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THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

AUGUST 1961

THE PRODUCTION ENGINEER

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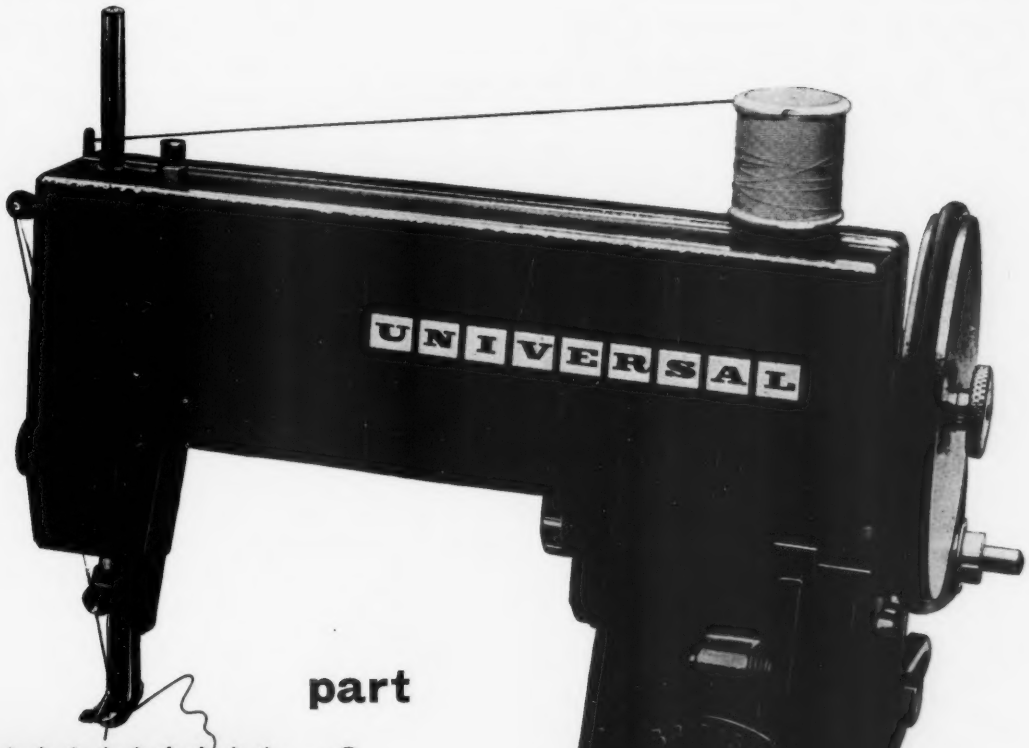

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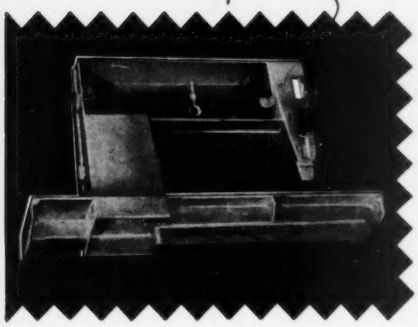

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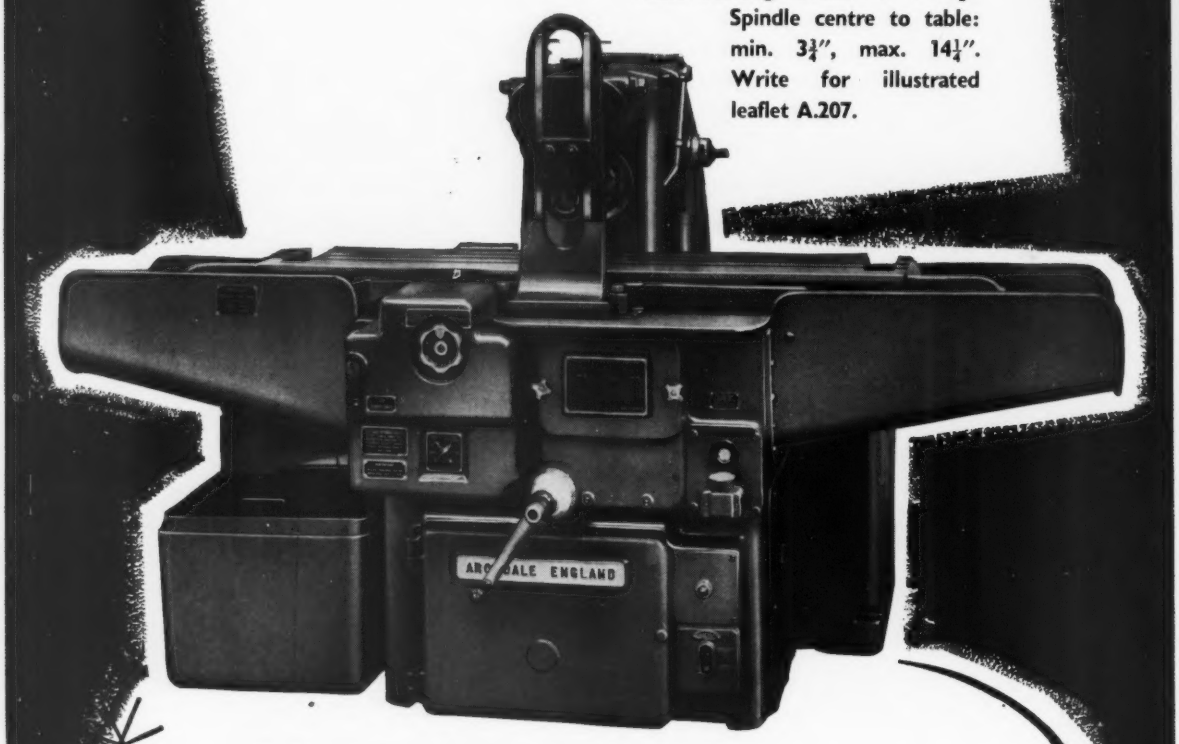

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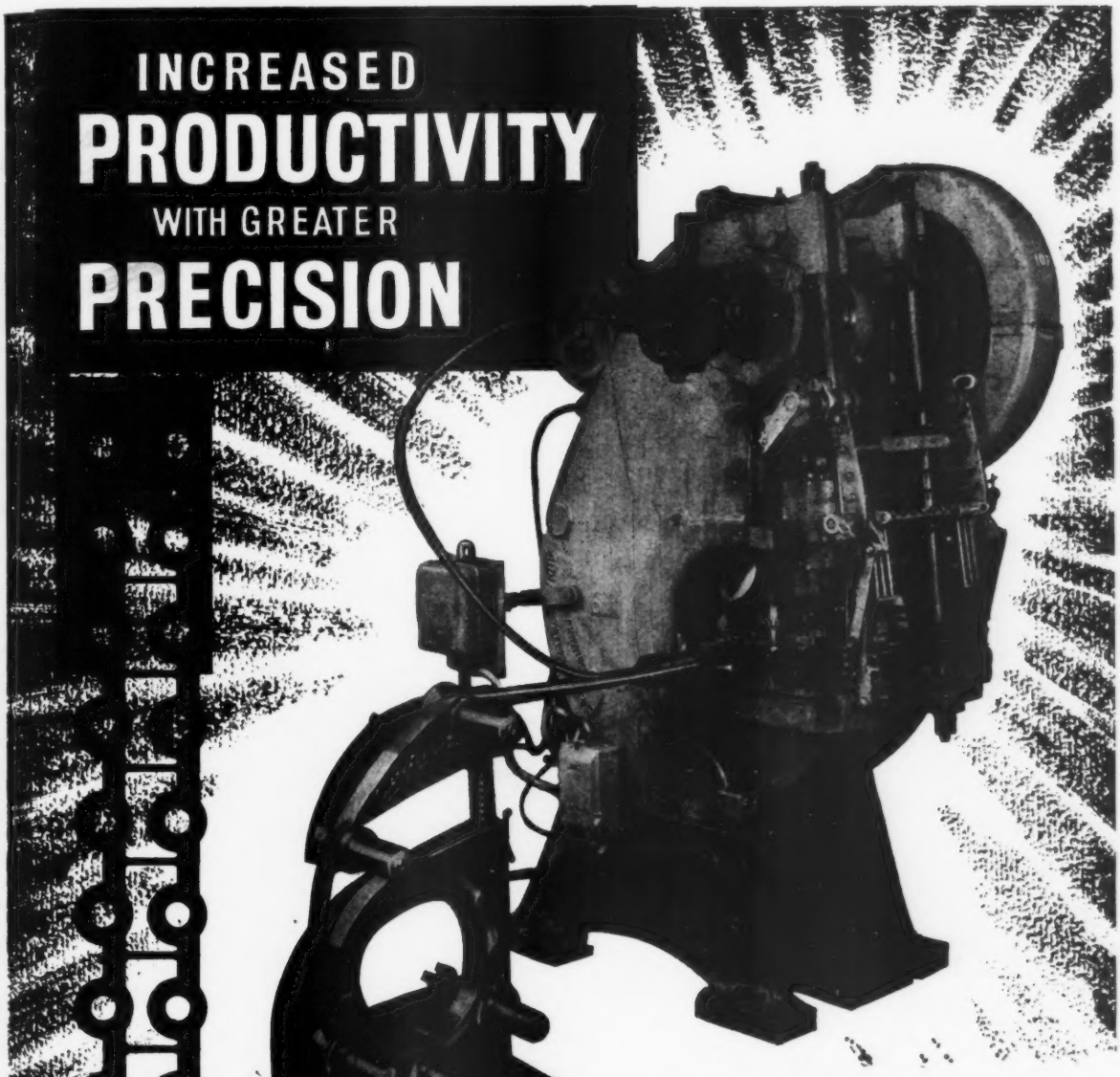

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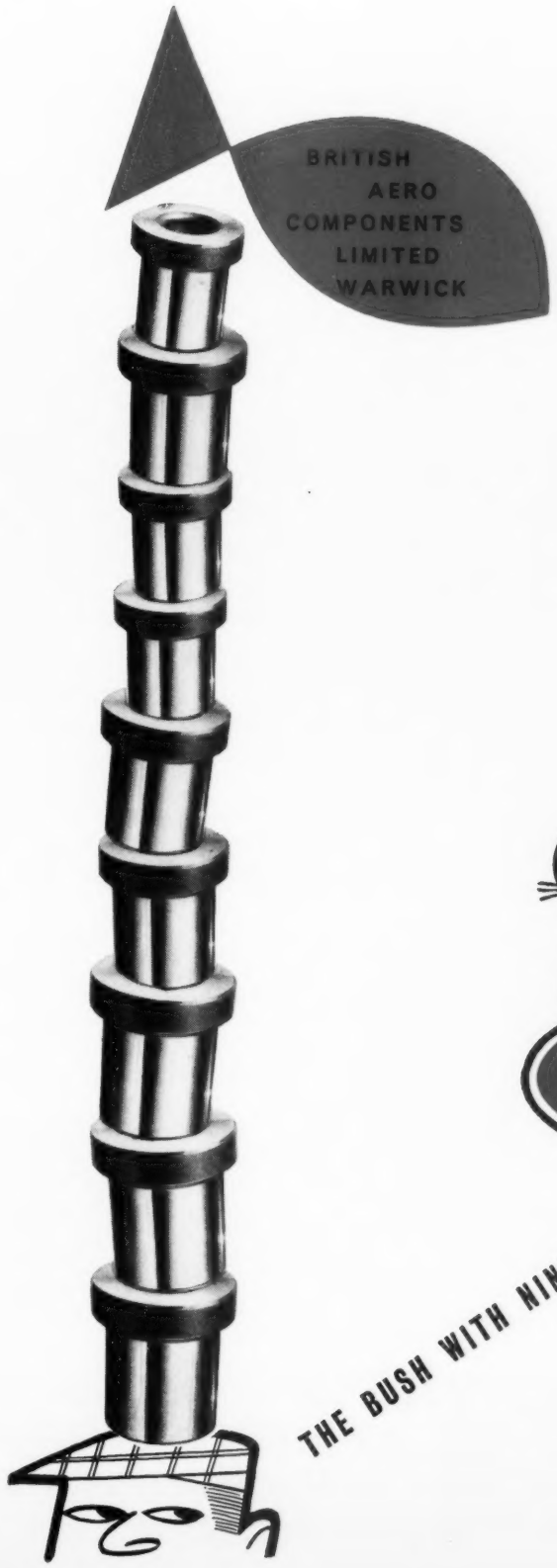

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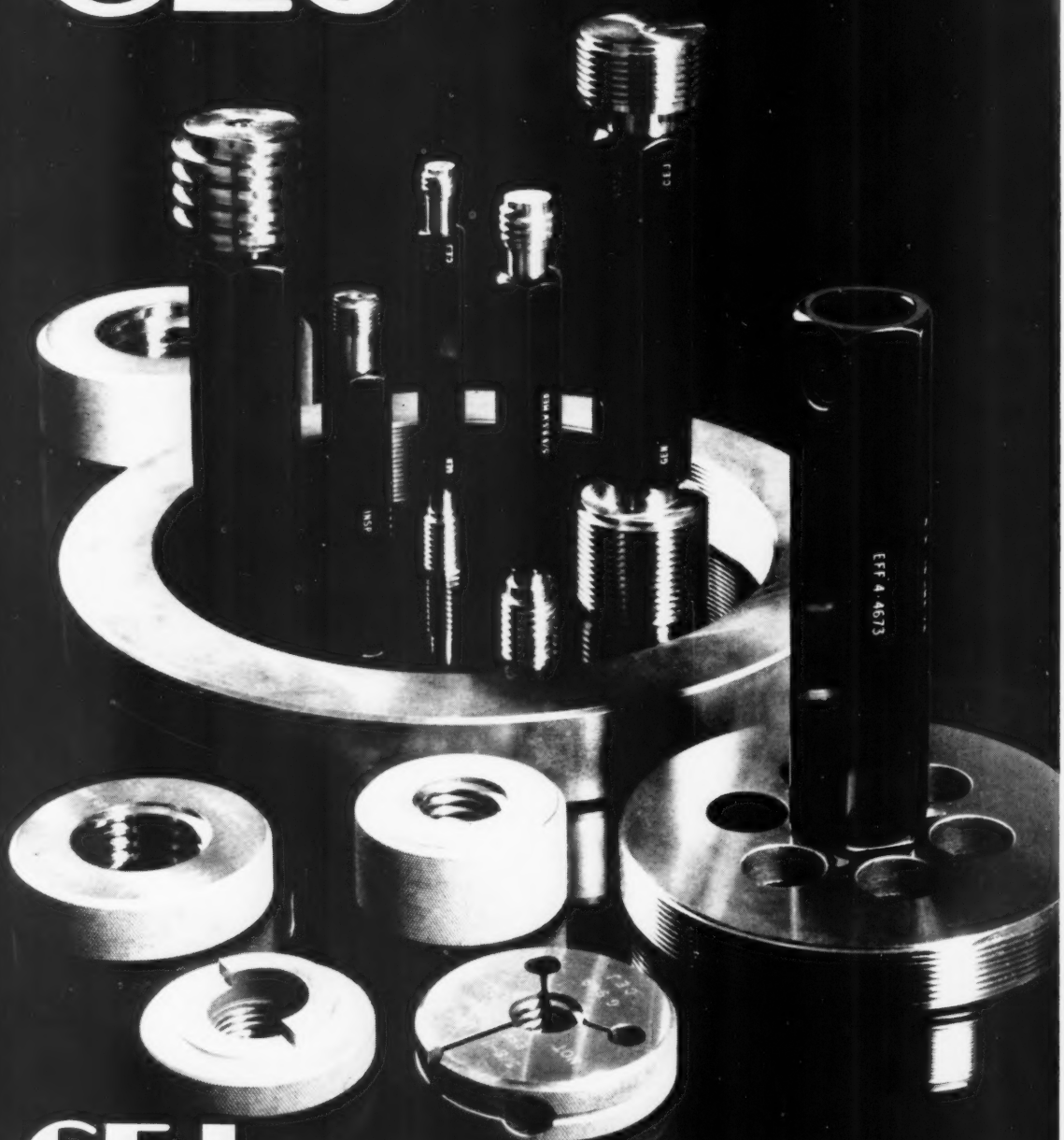

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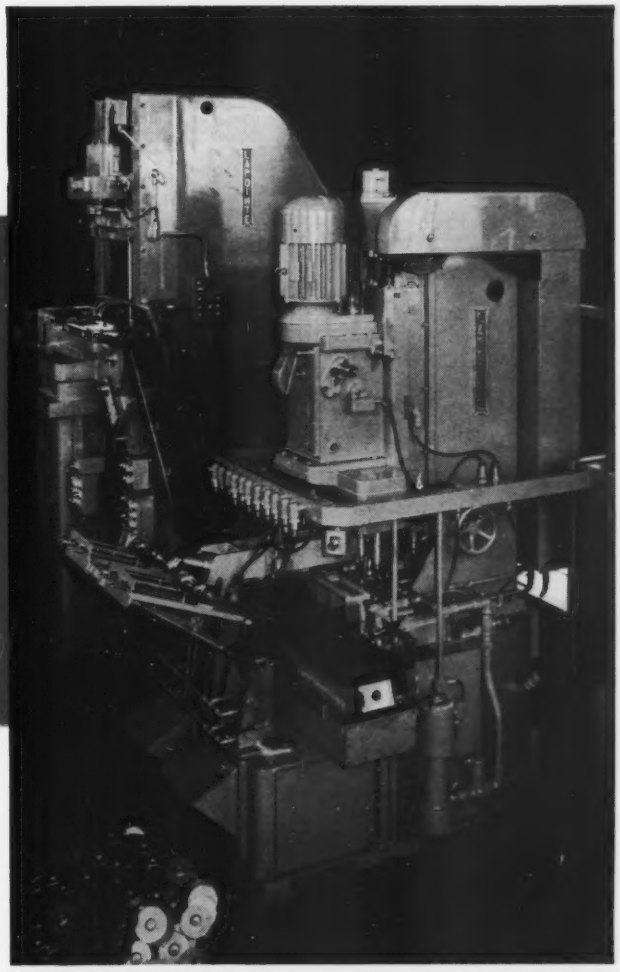

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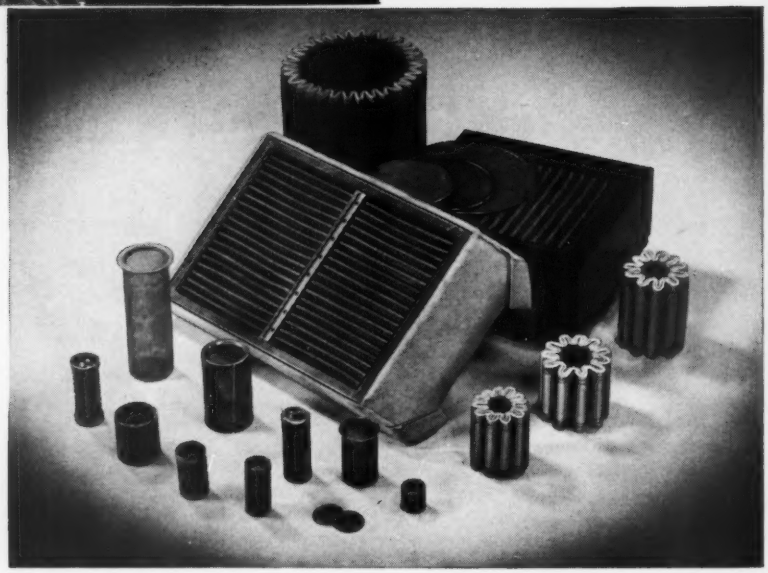

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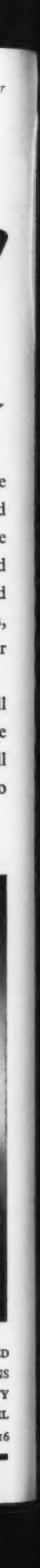

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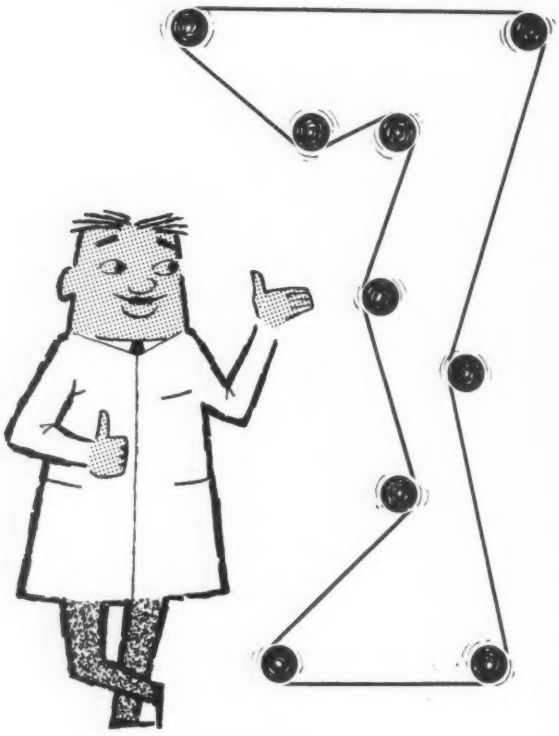

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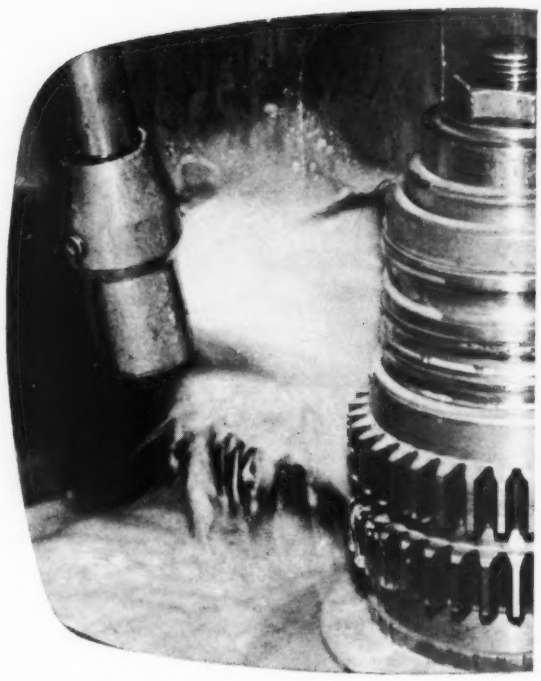

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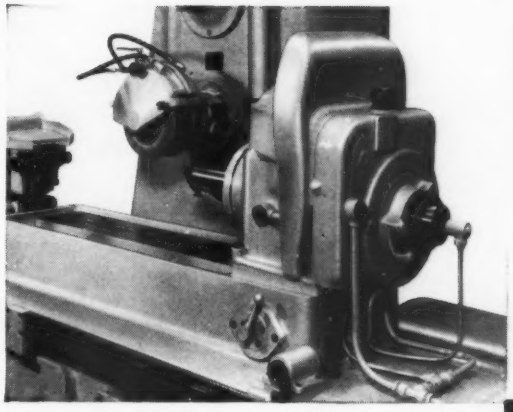

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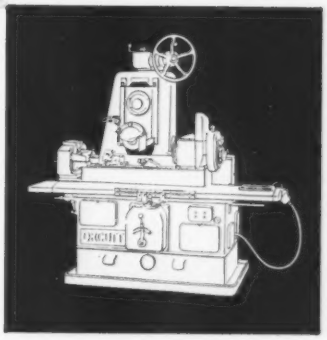

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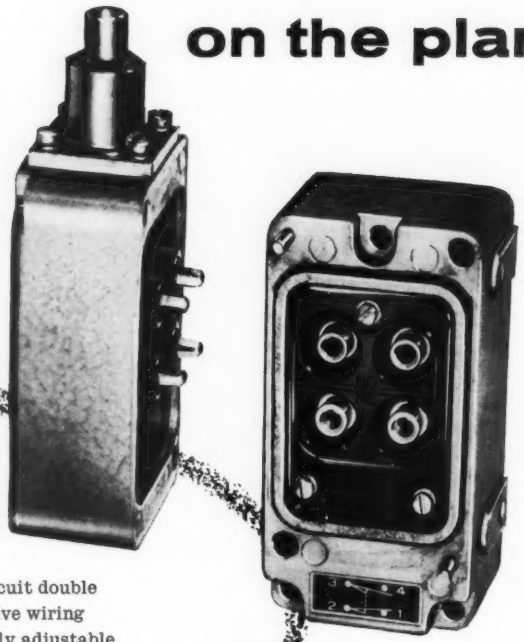

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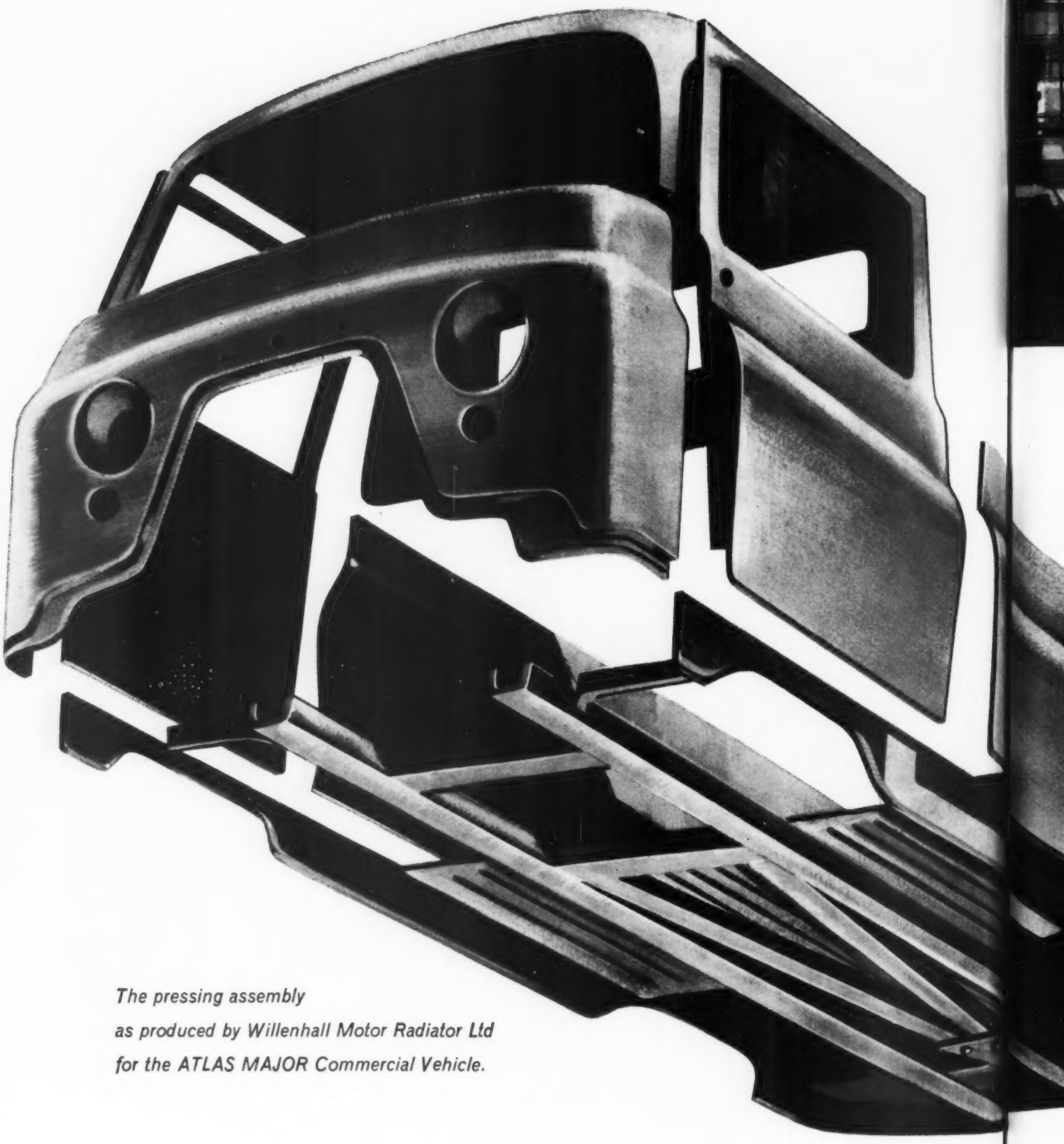
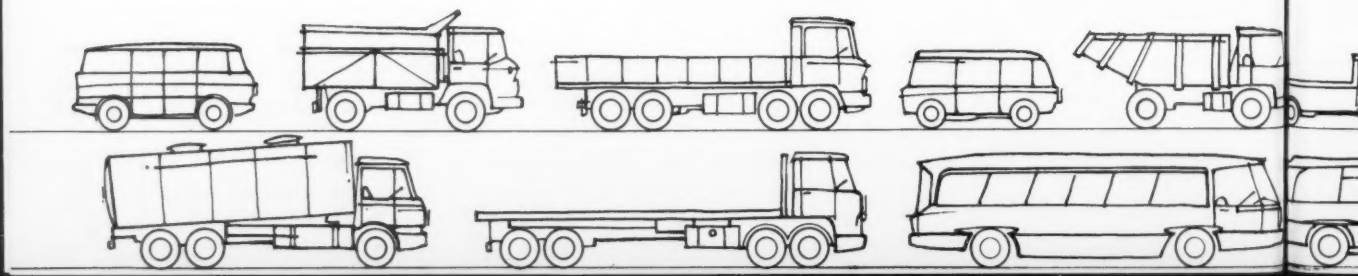
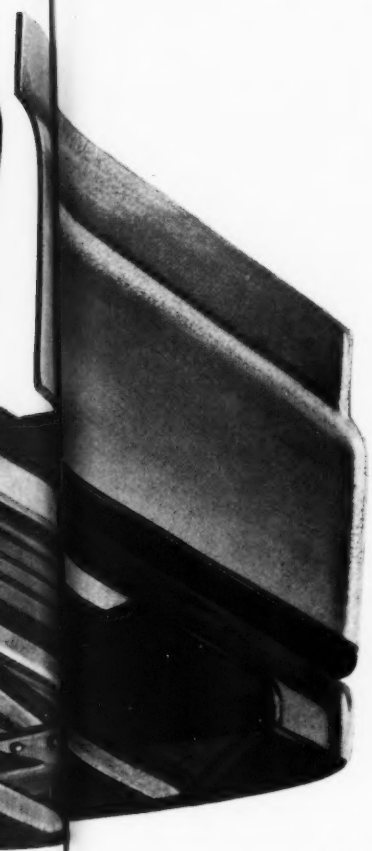


The pressing assembly
as produced by Willenhall Motor Radiator Ltd
for the ATLAS MAJOR Commercial Vehicle.



WILKINS & MITCHELL PRESSES (350, 400, 600, 800 tons capacity) at Willenhall Motor Radiator producing the pressings shown.



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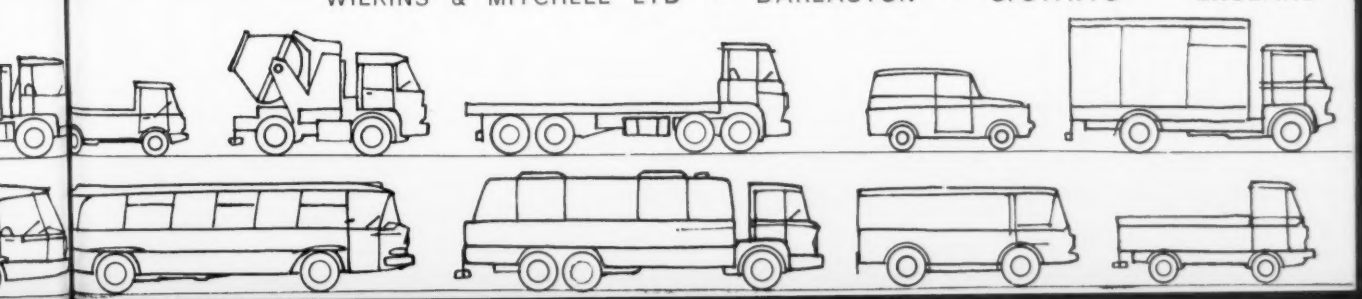

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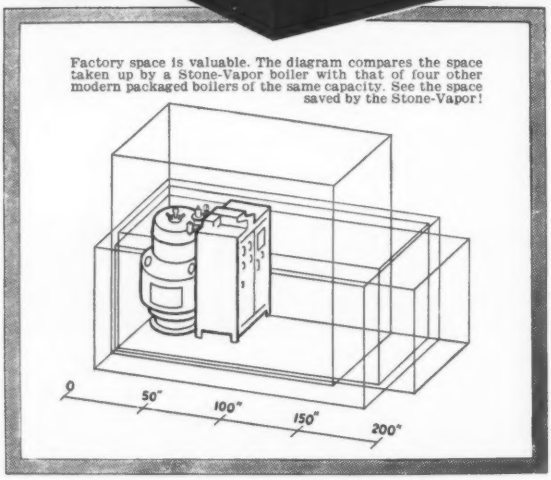

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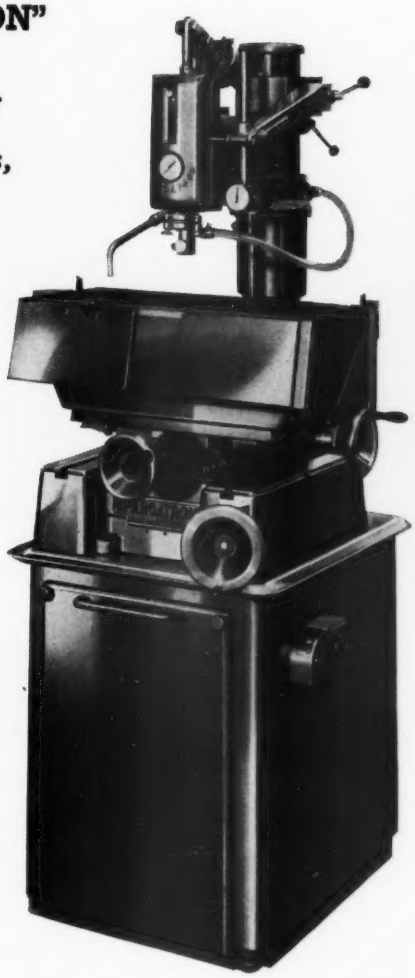

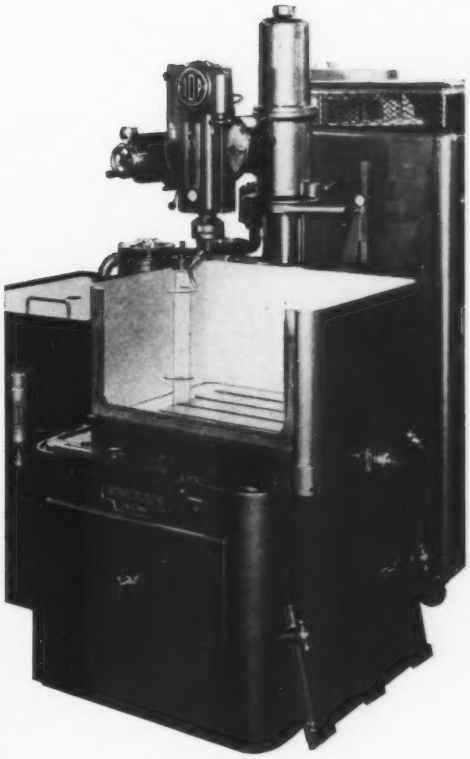

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Tank size Length 25" × Width 12" × Depth 7" Servo Head can handle electrodes weighing up to approx. 17 lbs. Mark IIIA is ideal in Toolrooms for the manufacture of Press Tools, Die Casting and Forging Dies.

Mk.V

Rapid stock removal of up to 6 cubic inches per hour.

Work-tank Length 42" × Width 24½" × Depth 16" (allowing for Die Block size Length 36" × Width 24" × Depth 14").

Servo Head handling electrodes weighing up to alternatively 50 lbs. or 100 lbs.

Both these machines are mechanically and electrically safe for automatic operation; complete isolation of the machine takes place on completion of the work.

Write or phone for details of the full Sparcatron Range

STEDALL MACHINE TOOL CO.

192-204, PENTONVILLE ROAD, LONDON, N.1

Telephone:– TERminus 3699 (25 lines)

Also at *BRISTOL, MANCHESTER, LEICESTER & GLASGOW*

TAPER BORING and

ILLUSTRATIONS

1

2

3

4

THREAD MILLING GRAPHITE ELECTRODES

at

ANGLO GREAT LAKES CORPORATION Ltd. with specially designed

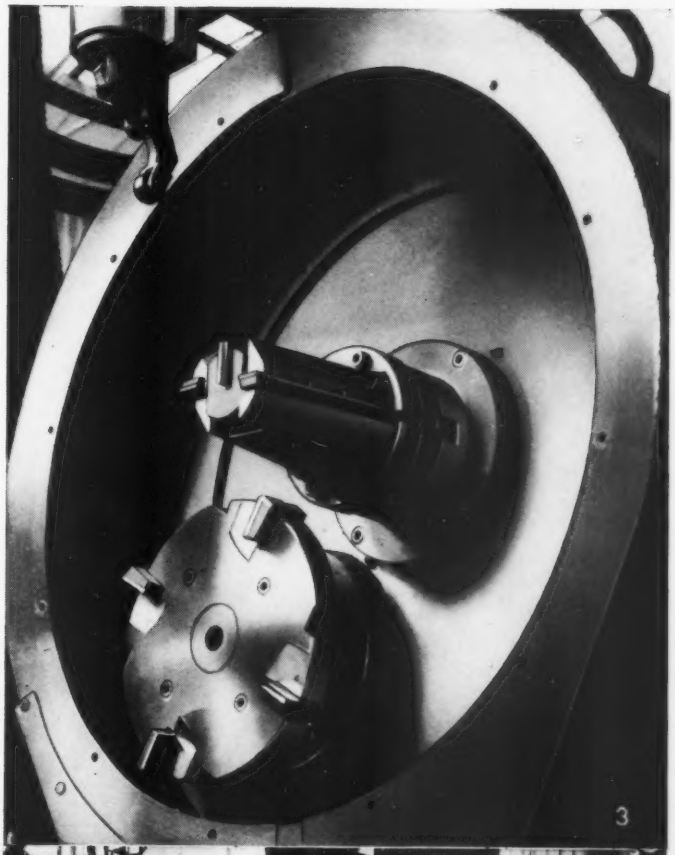
Galtona

INSERTED BLADE TAPER BORING, FACING AND THREAD MILLING CUTTERS

We illustrate one set of a range of tools supplied for milling graphite electrodes. The facing head shown on Fig. 3 has standard Galtona type serrated blades, carbide tipped, whilst the taper boring cutter has tipped blades held by means of wedges and screws, with one blade cutting to centre.

At Fig. 2 we show a thread milling cutter, having one blade in T.15 high speed steel secured by wedges and screws, with fine adjustment to facilitate setting-up.

We welcome enquiries for all types of inserted blade cutters, for which proposal drawings are submitted without obligation.



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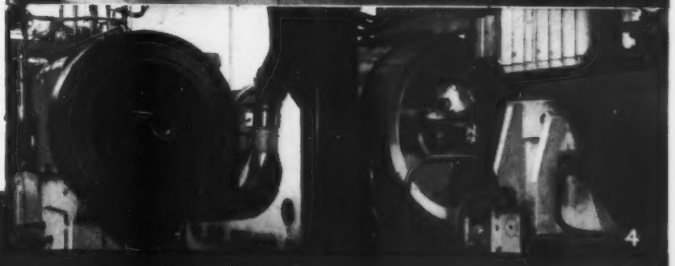

4

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GALTON HOUSE, ELMFIELD AVENUE, TYBURN, BIRMINGHAM, 24

Telephone: Ashfield 1801, Telegrams "Cogs, Birmingham"

No need for additional machines and extra floor space

DIMENSION INDICATORS

* Reduce stoppages for measurement after each cut.
* Increase machine utilisation and output.
* Reduce setting errors.
* Direct readings of workpiece dimensions give greater speed and accuracy.

Full technical details on request

English Numbering Machines Ltd.

Dept. 3K · QUEENSWAY · ENFIELD · MIDDX · HOWard 2611 (5 lines) · Grams: Numgravco, Enfield

I told the man from A & S –

there's a catch in it somewhere

Look, I've *seen* the Bridgeport in the States. Practically every machine shop over there has at least one of them. It is, as you say, more universal than a 'universal'—but of course you're not serious about the price. You don't buy milling machines out of petty cash. I'd cheerfully pay three times the price you mention for a Bridgeport like the ones I saw demonstrated —and I'd be willing to wait for it too.

So let's make sure we're both talking about the same machine. In the States, these machines are turned out at the rate of 130 or more per week, and yet demand has exceeded supply for twenty years. Correct?

In addition to every kind of vertical work, the Bridgeport can do right-angle milling, drilling, boring, profiling, slotting, cherrying, hydraulic duplicating and all the rest of it. Right?

Now then, do you mean to tell me you'll sell me the *identical* Bridgeport . . . what? . . further improved? Now 12″ cross traverse, more rigidity, increased versatility . . . enough! I warn you, I'm writing that impossible price into my order—one new Bridgeport Milling Machine for one third of the price it's really worth to me!

ONLY THE *Bridgeport* OFFERS SO MUCH

It's true!

Ask us for literature and details. We'll confirm the price in writing.

A&S

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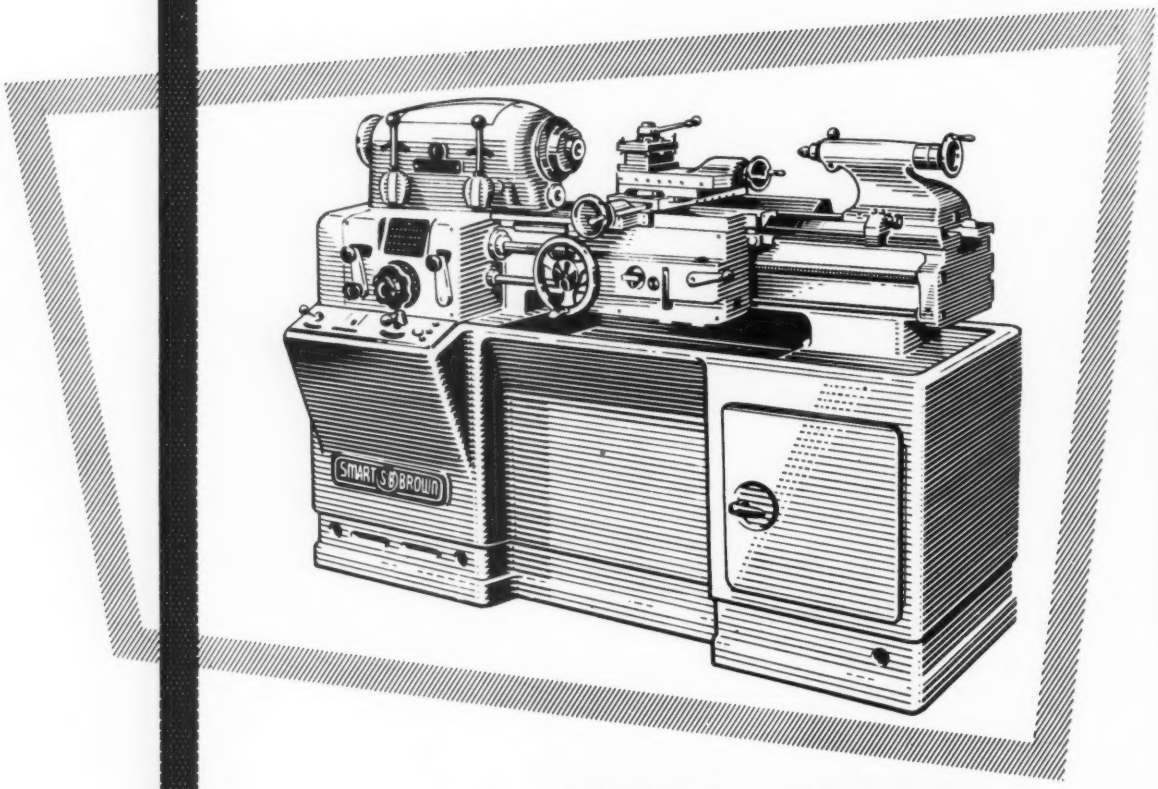
Precision Lathes....



the **SMART & BROWN**

MODEL 1024

S.S./S.C. TOOLROOM LATHE

Distance between centres: 24". 1" Collet capacity

12 Spindle speeds available: 30 to 2500 r.p.m.

Threads: 4—112 t.p.i.

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Model 1590—90 mm. Centre Height.

PULTRA micro lathes

The Pultra Capstan Lathe
is also available in 50 and 70 mm.
centre heights and can be supplied
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Production models.
Lathes can be equipped to your
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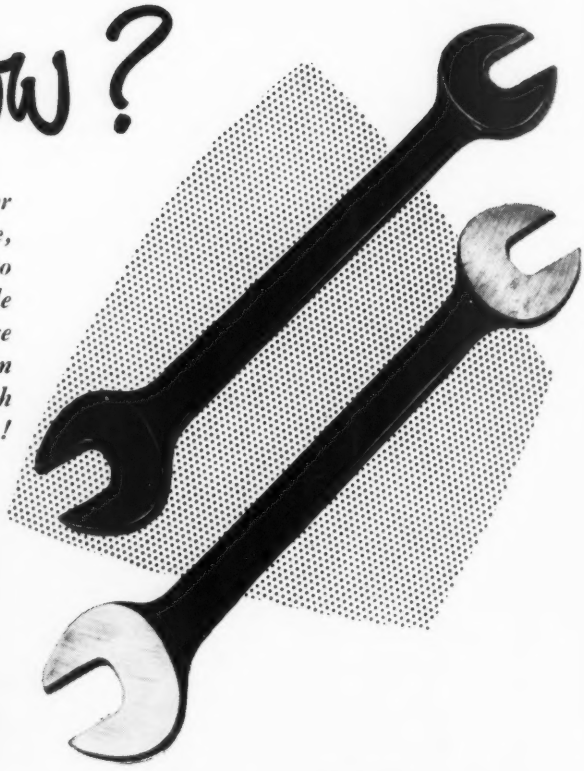
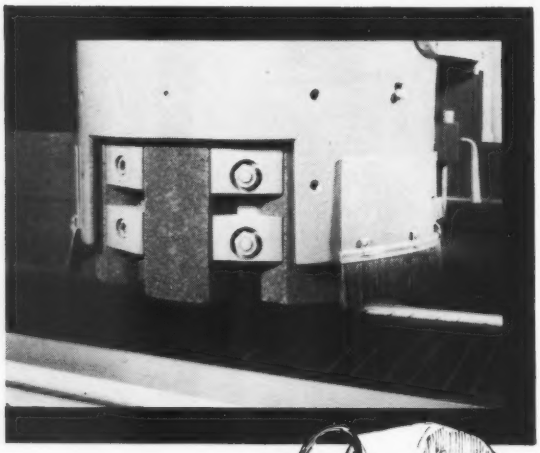
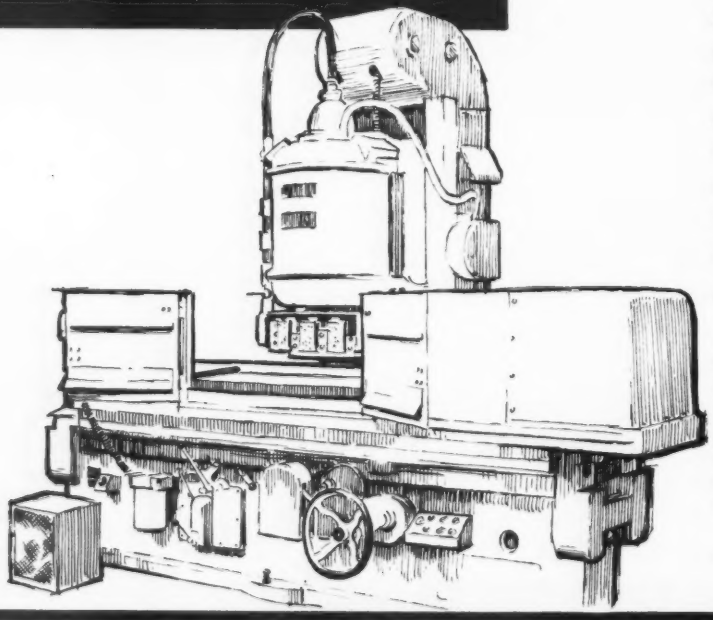
Do you know?

That you can get higher production with better finish at lower cost on vertical spindle, segmental surface grinding. By changing to ALOXITE vitrified segments, it was possible to reduce the abrasive cost of grinding these spanners by more than 5% – this is quite an item when you're grinding in quantities such as our customer does. And look at the finish!







Here are the production figures:

COMPONENT GROUND

Open-end spanners, 11″ long x $\frac{11}{16}$ and $\frac{3}{4}$ Whit.

MATERIAL

EN47 chrome vanadium alloy steel.

ABRASIVE

Segments AA46 — J5 — VL.

NUMBER GROUND

200 dozen spanners per set of 6 segments.

ABRASIVE COST

4·35 pence per dozen.

•

CARBORUNDUM can help you to achieve this kind of production and economy. And not only on segmental grinding. Whatever your grinding process, whatever your problem, we have experts who can advise on the best and most efficient use of abrasive materials.

Write and ask for a representative to call.

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WERNER the only **Standard** Milling Machines with automatic table cycles at no extra cost.

WERNER **Standard** Milling Machines are built with table sizes up to 98″ x 24″ with 67″ travel.

WERNER **Standard** Milling Machines are available in horizontal, universal and vertical types.

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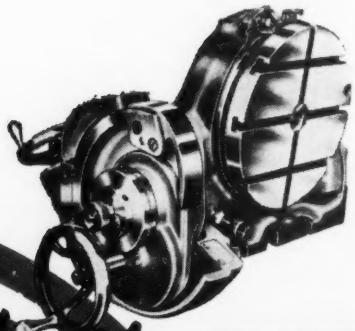
W.16

HAND OPERATED
PLAIN TYPES



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FIRST CHOICE FOR PRECISE
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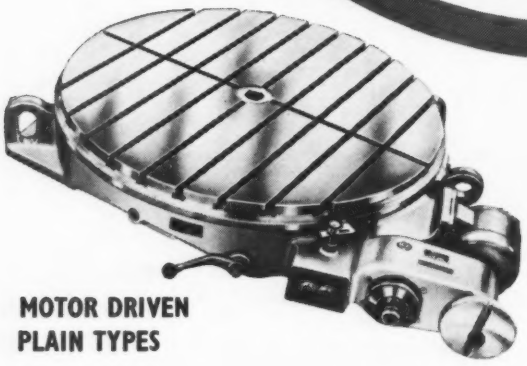
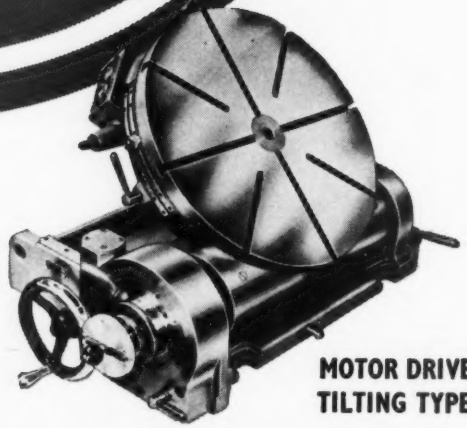


MOTOR DRIVEN
PLAIN TYPES



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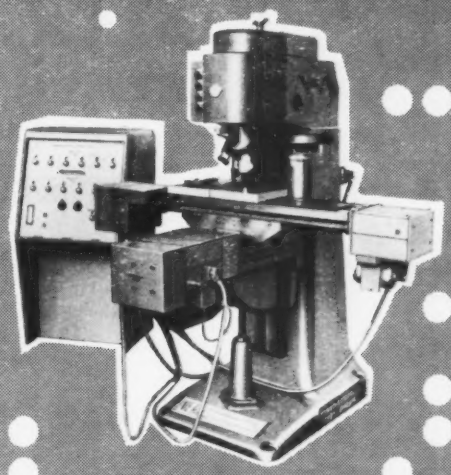
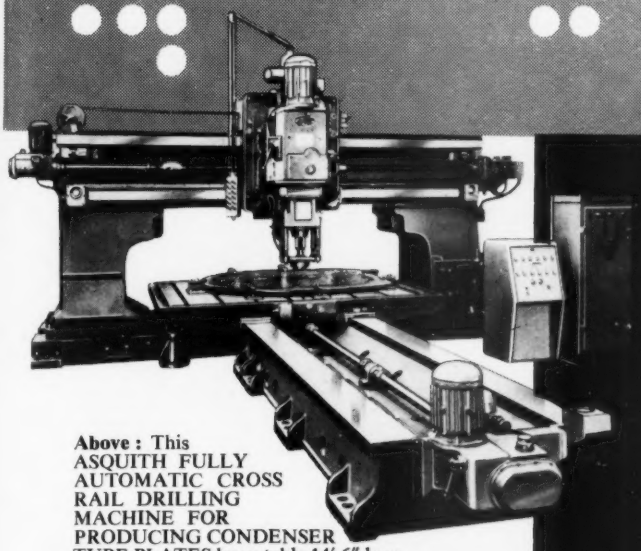
Gets those Drilling Jobs taped





Above : This ASQUITH FULLY AUTOMATIC CROSS RAIL DRILLING MACHINE FOR PRODUCING CONDENSER TUBE PLATES has a table 14′ 6″ long ×10′ wide. Controlled by the AIRMEC AUTOSET, the overall accuracy of positioning is better than .005″.
Manufacturer: William Asquith Ltd., Highroad Well Works, Halifax, Yorks.

Top right : Airmec Autoset fitted to Vero Auto-drill. 6 spindle Turret Head — 36″ × 9″ table. Spindle speeds 300 - 6,000 r.p.m. — $\frac{1}{16}$″ drill capacity.
Full details available from:
Catmur Machine Tool Corporation Ltd., 103 Lancaster Road, London, W.11.

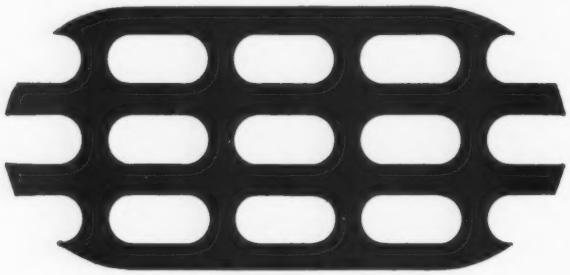
Airmec

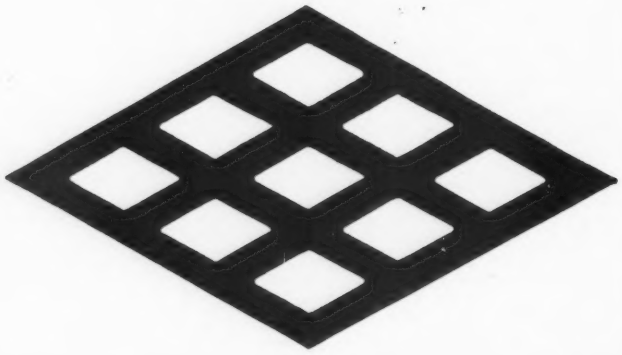
AUTOSET
Low cost tape control

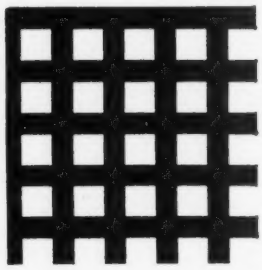
AIRMEC LIMITED · High Wycombe · Bucks Tel: High Wycombe 2501/7

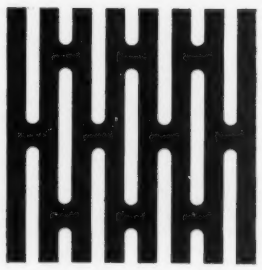
PERFORATIONS IN PROFUSION

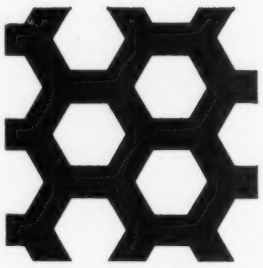
Braby

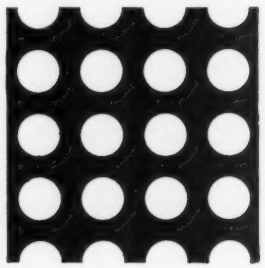












When it is a question of shape, think of the variety Braby Perforations offer — rounds, squares, diamonds, hexagonals, slots and ovals in a host of sizes and arrangements. When it comes to applications, consider their perfect suitability for screening plant, acoustic panels, filters, silo floors, machine guards, accumulator plates, decorative radiator and pipe guards, cable trays, food strainers and a variety of uses in the electrical industry.

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HYDRAULIC POWER PACKS

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THE 'MIDGET'
THE 'MINOR'
THE 'MAJOR'
THE 'MIGHTY'

Keelavite power packs provide a range of self-contained hydraulic power units suitable for many widely differing industrial applications. A large number of pumping capacities are available. All packs are so designed that the valves most suitable for the customer's requirements can be fitted. Standard units from the enormous Keelavite range are used.

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. . . When you require a mobile hydraulic power unit. A caster mounted pack is ideal for operating a battery of hydraulic jigs and tools in intermittent use.

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. . . when size and weight restrictions are imposed. Mount the pack alongside the machine and just couple up to the actuators.

Name	Dimensions: less height of motor	Tank Capacity	Electric Motor H. P.	Pump Capacities
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The MINOR	30"x16"x16½"	20 gall.	up to 5	suit
The MAJOR	40"x24"x16½"	50 gall.	up to 12½	customer's
The MIGHTY	40"x24"x24"	75 gall.	up to 25	requirements

introducing an entirely new
Power Pack of which you will want details

The KEELAPACK

A desk top console which houses the complete hydraulic system. Hydraulic and electrical controls neatly contained in minimum space. Custom built from standard components.

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KEELAVITE COMPLETE HYDRAULICS
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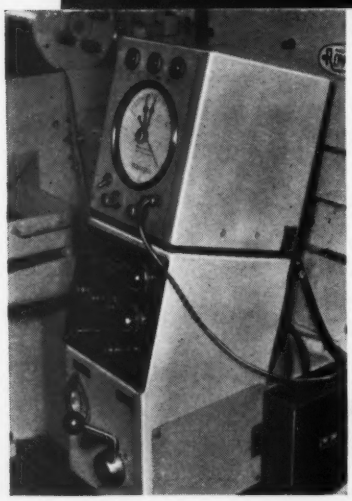

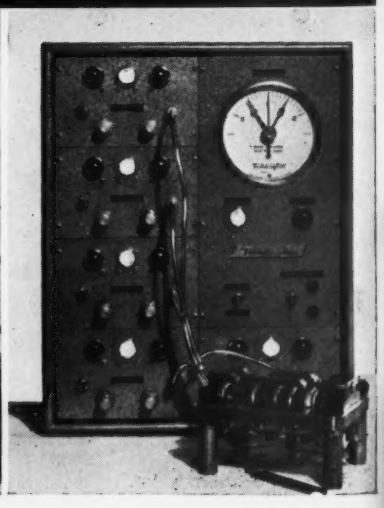

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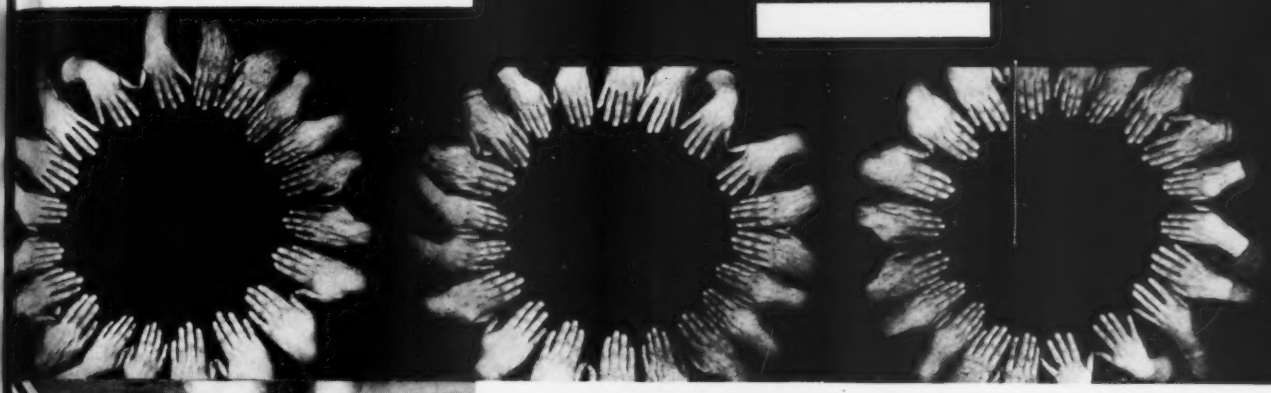
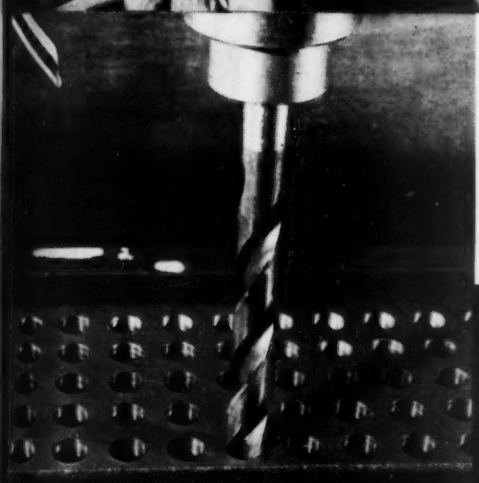




It takes at least 30 people — 30 pairs of skilled hands — to make one DORMER Drill. Every operation is performed by experienced operators with the most up-to-date machinery. Careful heat-treatment and inspection are equally essential in maintaining the consistently high standard of DORMER Tools.

INSPECTION

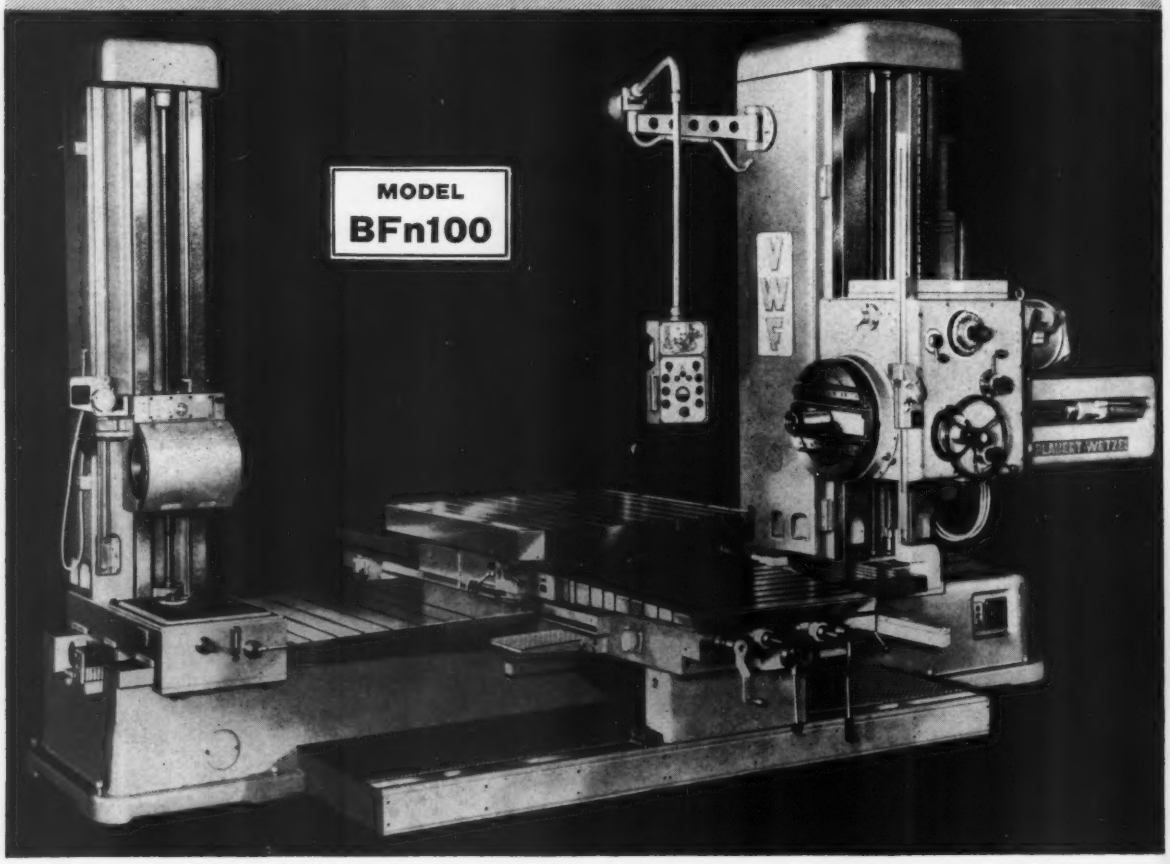
ith correct use, a DORMER Drill of 1 in. meter, in its lifetime on general purpose rk, will remove 2,800 times its own weight material (over $1\frac{3}{4}$ tons), and drill a total gth of hole 500 yards long!

DORMER

TWIST DRILLS
THE FINEST BY ANY STANDARD

VWF PLAUERT-WETZEL

Horizontal Boring and Milling Machine



★ Boring and milling spindles can be engaged individually or together, at identical or different speeds.

★ Pre-selection of a wide range of spindle speeds and feeds, controlled from pendant station.

★ Precision scales for co-ordinate settings. Optical fine setting equipment available as an extra.

★ Rapid tool clamping in boring spindle by steep angle taper and quick-acting locknut.

★ Adjustable, hardened outboard supports for the table slide; included as standard equipment.

★ Fully automatic, timed lubrication of slideways, feed mechanism and spindles.

A brief description of Model BFn 100

Table dimensions	50 in. × 55 in.
Table load, max.	8 tons
Distance between faceplate and steady	124 in.
Height of work spindle above table	0–55 in.
Cross and longitudinal traverse of table	69 in.
Boring spindle diameter	3.94 in.
Milling spindle diameter	7.09 in.
Boring depth in one traverse/with resetting	35/49 in.
Maximum diameter bored	35 in.
Facing diameter, max.	44 in.
Spindle speeds	9–1400 r.p.m.
Rapid traverse (all directions)	138 in./min.
Main motor	20 HP.
Weight (net, with steady)	17 tons

Other models are available

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SYKES

Machine Tool Co. Ltd

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Staines 55474 (5 lines)
Telegrams Sytool Staines

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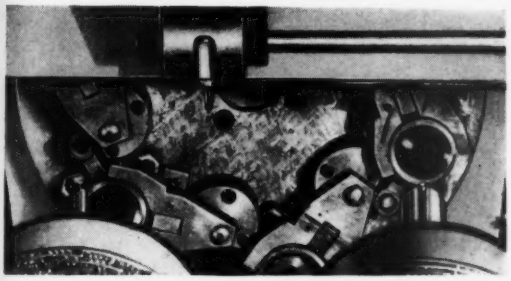
BETWEEN THESE RODS

— BOTH ARE BORED TO EXACTING STANDARDS

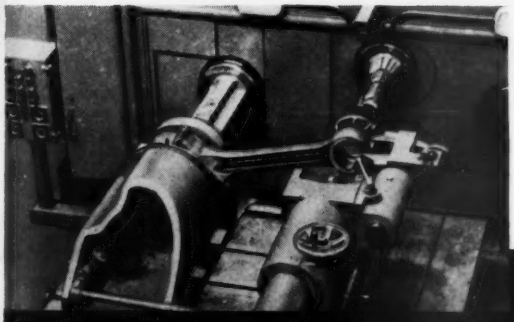
the PRECIMAX way

Cast iron. Weight 6 oz.

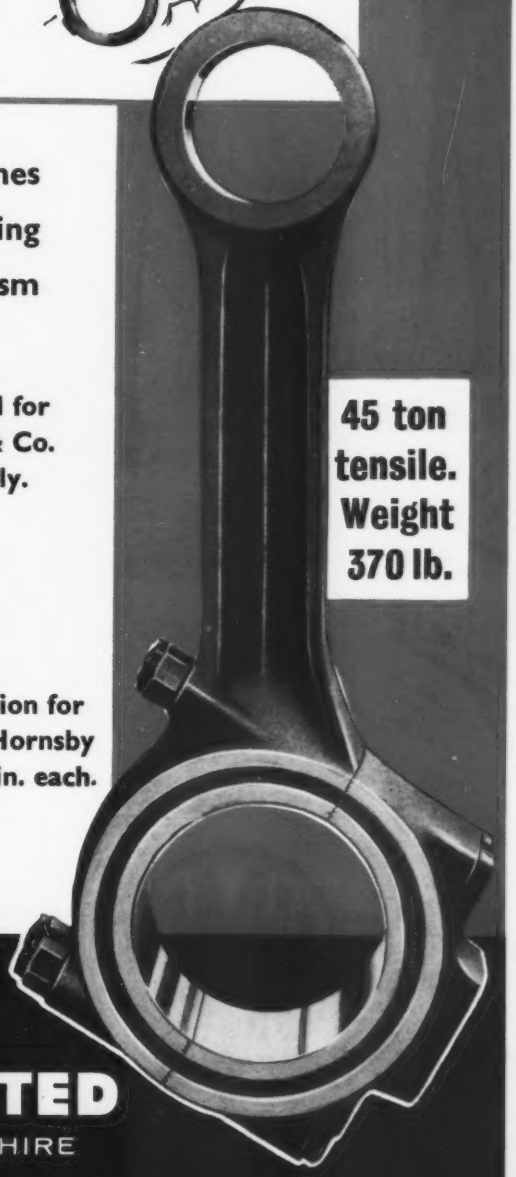
Single Ended Fine Boring Machines finish bore these workpieces to exacting tolerances of roundness and parallelism each end.



6 oz. model for L. Sterne & Co. at 120 hourly.



370 lb. version for Ruston & Hornsby takes 13 min. each.



45 ton tensile. Weight 370 lb.

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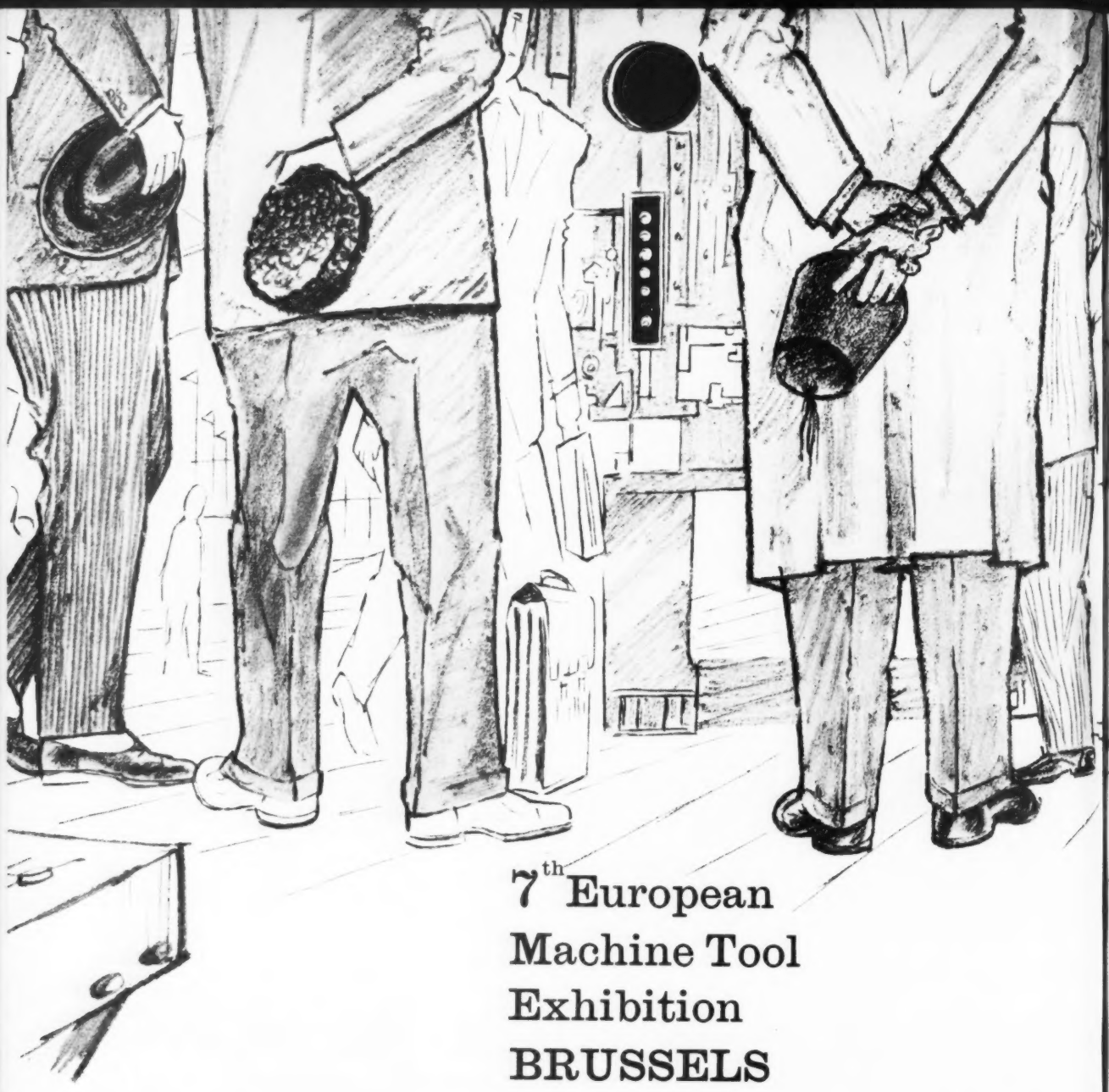

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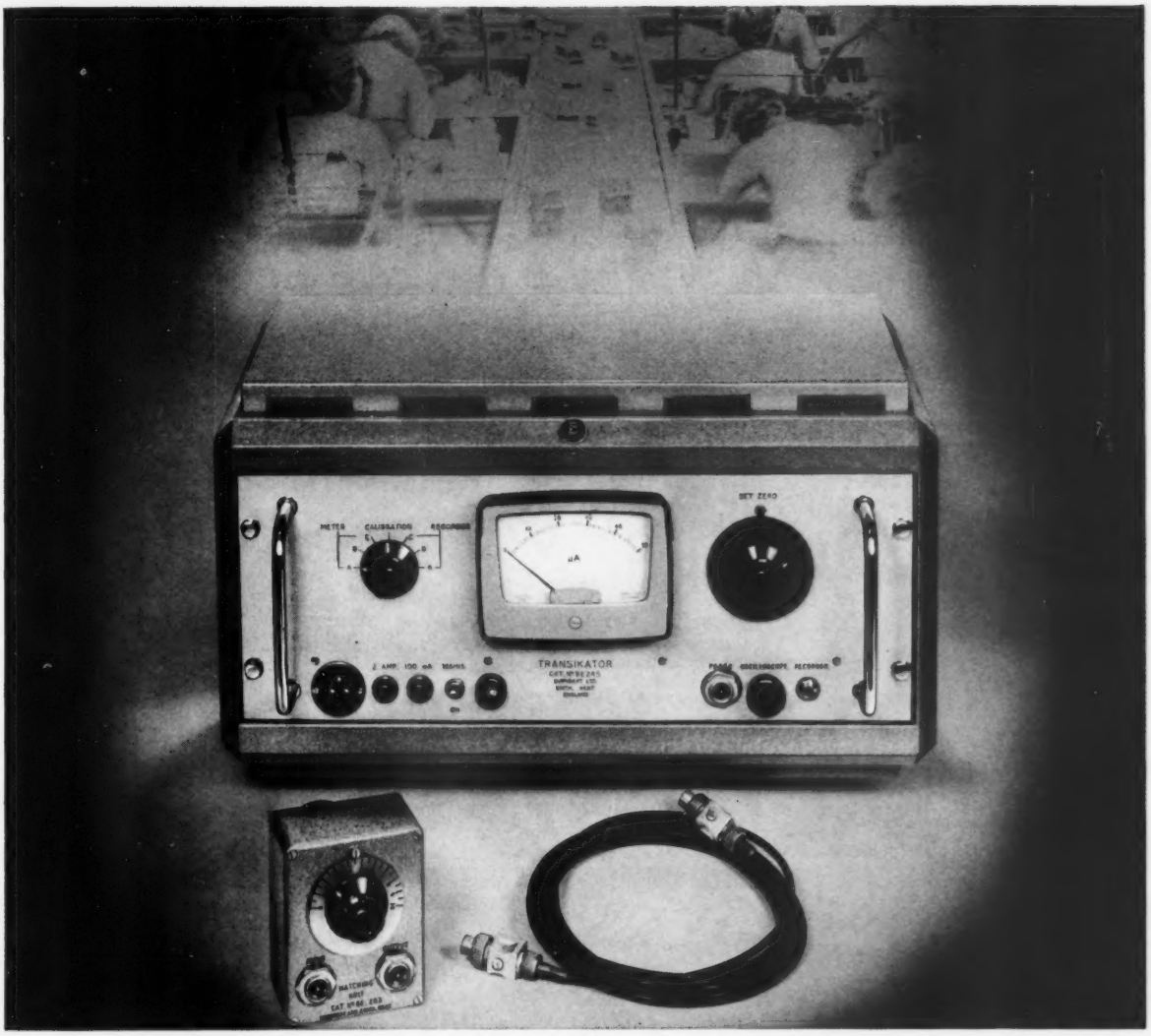

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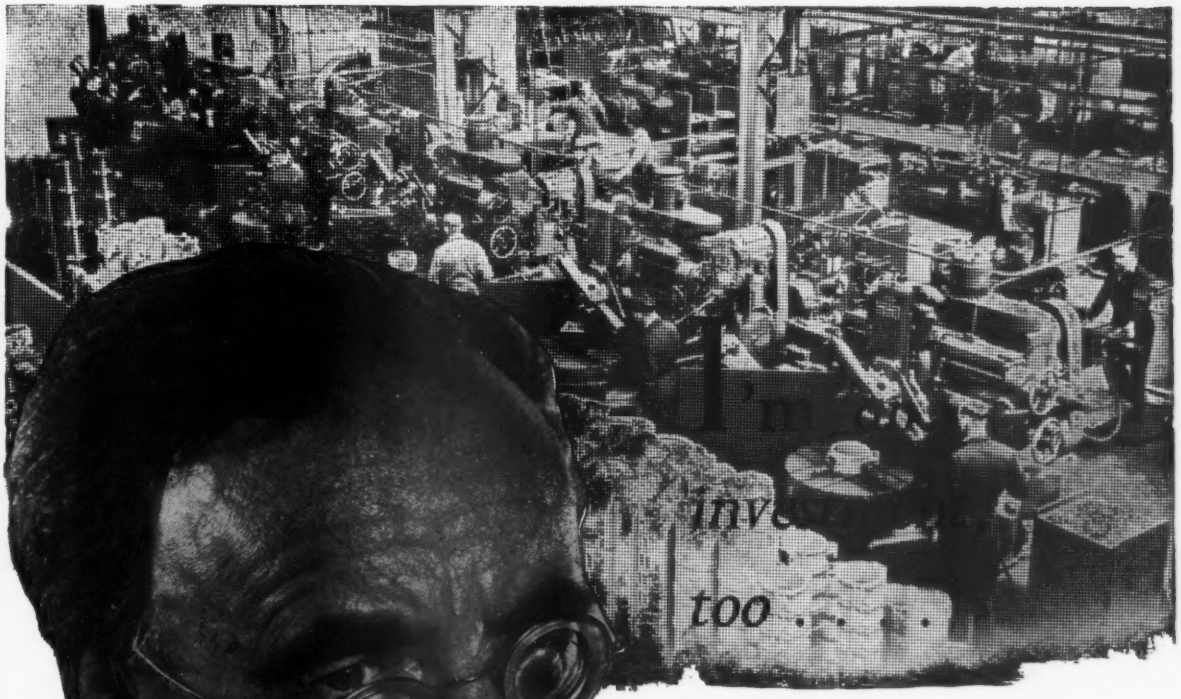

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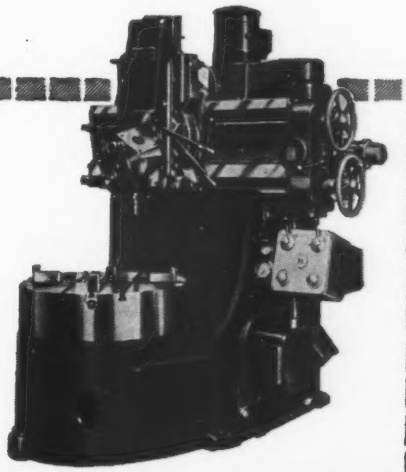

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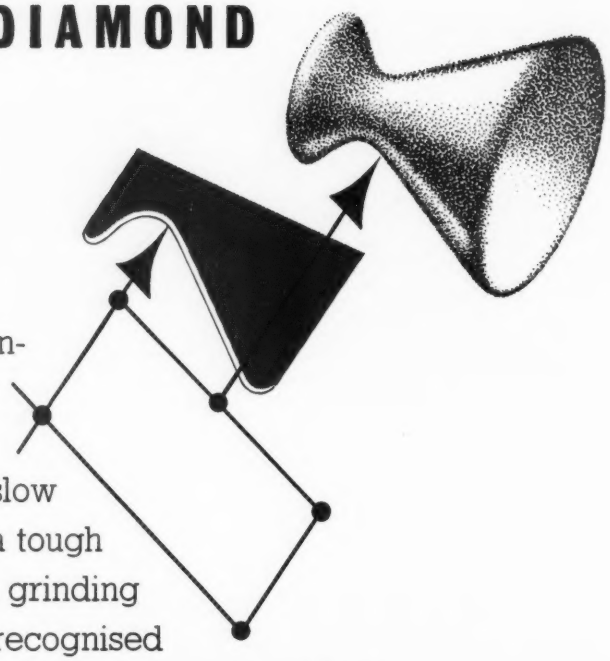

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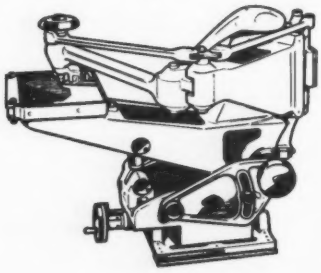

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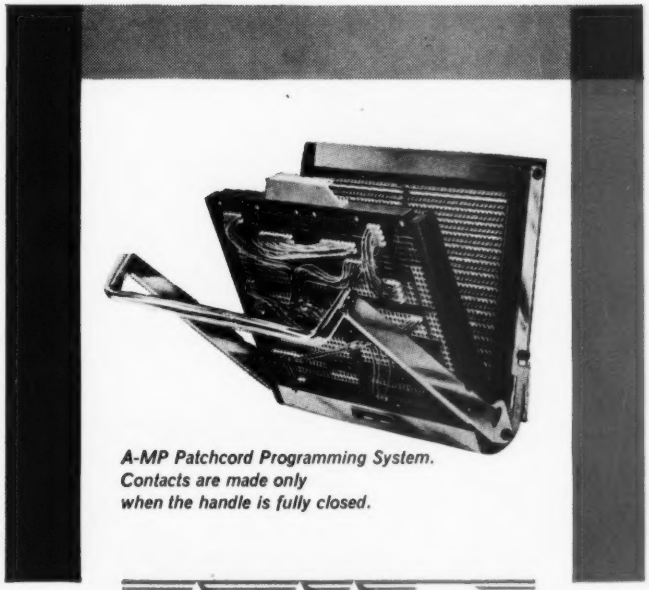

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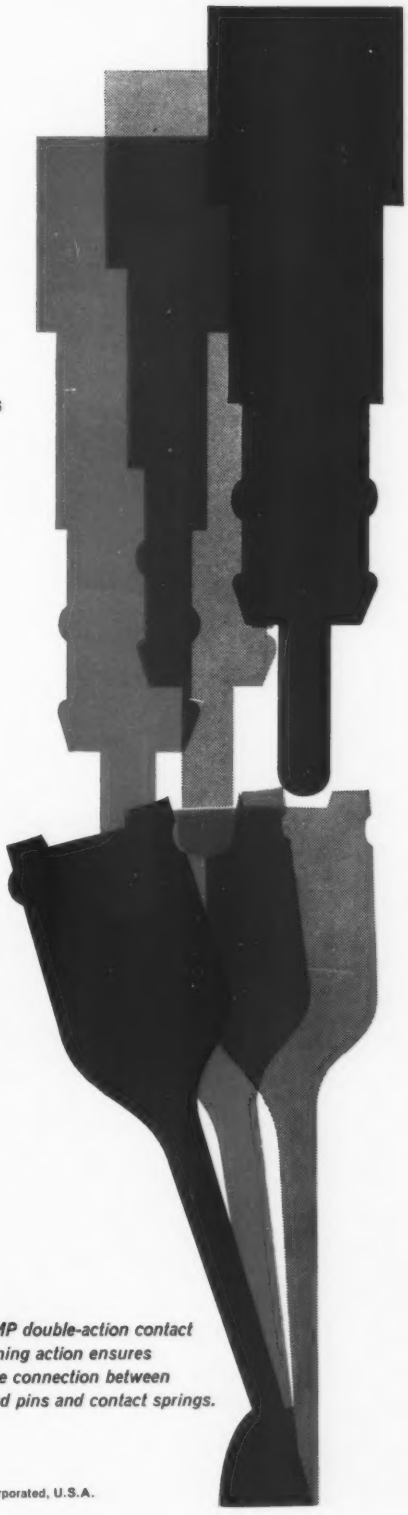

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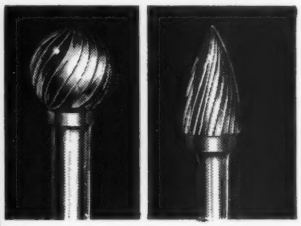

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The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 40 No. 8 AUGUST, 1961

THE EFFECT OF NATIONAL CHARACTER ON PRODUCTION METHODS

by E. P. WARD, M.A., A.M.I.Mech.E.

In this Paper, presented to the Western Section of The Institution of Production Engineers in January, 1960, the author describes how scale of operations, level of development and planning philosophy can affect a nation's attitude towards automatic and mechanised production, and compares current practice in the Soviet Union, the United States of America, and the United Kingdom.

WHEN I was called upon to talk about production engineering in the United States, the Soviet Union and the United Kingdom, I felt rather as if I had been asked to review the whole of human history in a few well-chosen words. It certainly gave me ample scope. My qualifications to speak on such a subject were also somewhat tenuous: in two of the countries I had spent a bare total of five weeks; in the third, where I had passed the remainder of my life, I had never had cause to look closely at production methods. Indeed, my knowledge of production engineering is so limited that normally I should only have the temerity to discuss it in the presence of painters, poets, housewives and historians — but never engineers. My neck is well and truly out; I only hope that in the subsequent discussion my audience will go easy with the chopper.

To protect myself, I should like to define my purpose within more modest terms of reference. I propose to examine as a layman the social, economic and political conditions in the three countries and see to what extent they govern the introduction of automatic production methods. I hope that, as a layman, I may be able to present a point of view which though inexpert may be at least provocative.

The three countries may be compared under three main headings:

effects of central planning;
effects of abundance; and
effects of scale.

I shall attempt to show to what extent these three factors influence the introduction of automatic methods. To illustrate my arguments I shall examine Soviet production engineering in special detail.

effects of planning

It is common knowledge that the Soviet Union favours a planned economy whereas the West prefers its evolution to proceed organically. But the implications of this distinction for production engineers may not be so familiar. Thus long-term considerations are primary to the Soviet system, while in the West fundamental research, large-scale re-equipment programmes and, for that matter, military preparation, have come later, as the by-products of wealth, not its preliminary. With their concern for the remoter future, the Russians may be prepared to consider massive investment programmes when Western industrialists would tend to be more cautious.

This tendency is amplified by the need in the West for companies to diversify, as a precaution against a failure in the demand for a single product. The Russians, with their centrally or regionally planned economy, can afford to specialise, leaving losses on the swings to be balanced on the national roundabout. Inevitably Western resources are much more subdivided, and this greater fragmentation leaves fewer eggs to be committed to the single basket of an automatic factory. Even an integrated production line would be a major risk for any but the largest Western manufacturer. Recent news that Soviet engineers have started to mass produce capital equipment, such as machine tools, confirms their eagerness to centralise production.

Different attitudes towards the use of capital further increase the divergence between East and West. In a planned economy, for example, there appears to be no effective mechanism whereby the use of capital plant is subject to retrospective influences, through interest payments and depreciation.

In the West there is always considerable pressure to recover the expenditure on a new machine by using it to the full. We are like the man who insists on occupying the deckchair he has paid for, notwithstanding the onset of a downpour. Thus, to obtain the most favourable operating figures for our costly nuclear power stations we propose to use them exclusively on base load, so that other stations, somewhat unjustly, must be made to operate at less economic load factors.

The Russians, on the other hand, make such calculations as they can before installation; the capital then appears to be written off. Afterwards, the machine is only used to an extent consistent with the requirements of the overall production process.

This approach is not always as beneficial as it would seem. There is, for example, less incentive for a production manager to secure the optimum combination of plant in the first place. Because flow-line production is attractive, a machine of sufficient capacity to serve two lines may be inserted in a single integrated line, when it would be far better to use it fully and install broken lines with rather more inter-machine handling.

The result of this difference in outlook may be most effectively shown by examples outside production engineering. I travelled twice in Soviet aircraft capable of seating 30 - 40 passengers but only carrying a few. And I was always being encouraged to make long-distance telephone calls and told how cheap it was. The reason seemed to be that specific running costs of a telephone system were comparatively low, so that calls were cheap and the system therefore highly loaded; while operating an air service was expensive, so that fares were high and aircraft under-utilised. In both cases capital costs seemed to be ignored, leading, I believe, to considerable misapplication of basic resources.

There would also be a tendency to hold materials and components in stock for longer periods than economically desirable. A company can either hold stock or its equivalent in capital; the capital brings interest, stock does not. In Russia the incentive to secure the greatest return for capital does not apply with the same force as in the West, so there is little encouragement to eliminate unnecessary stocks.

use of computers

The use of computers in America for stock control is well-established. A representative of IBM told me that a changeover from punched-card to computer operation had made it possible in one case to reduce inventory by 30% to 40%. Since details of stock are accurately known and immediately accessible a smaller margin for error needs to be allowed, with consequent saving in space and inventory cost. Such economies would only be effective where costing procedures were based on a desire to recover capital outlay.

It will be apparent that where the incentive to use existing equipment is weak, and where it is unnecessary to employ all machines in a workshop to an extent related to their initial cost, it is far easier to install integrated production lines, in which the utilisation of each machine is solely determined by the requirements of the overall process.

The Russian planners, with their long-term approach, set great store by research, even research with only a remote prospect of practical application. But whereas Western research began as a pursuit of fundamental knowledge, largely for its own sake, and then narrowed its attention to practical problems of engineering, the Soviet research worker started as a practical man and only enlarged his vision as the rewards of basic study became apparent. "There's no research so pure it hasn't any progeny", an American naval officer remarked to me. The Western scientist accepts pure research and justifies it on practical grounds. The Russian accepts practical research and justifies its extension to fundamental problems.

It is this outlook that leads the Russians to set up research institutions for such special areas as cybernetics, "telemechanics", process control and automation. It is as if they have considered the technical requirements of the future, realised that to tackle

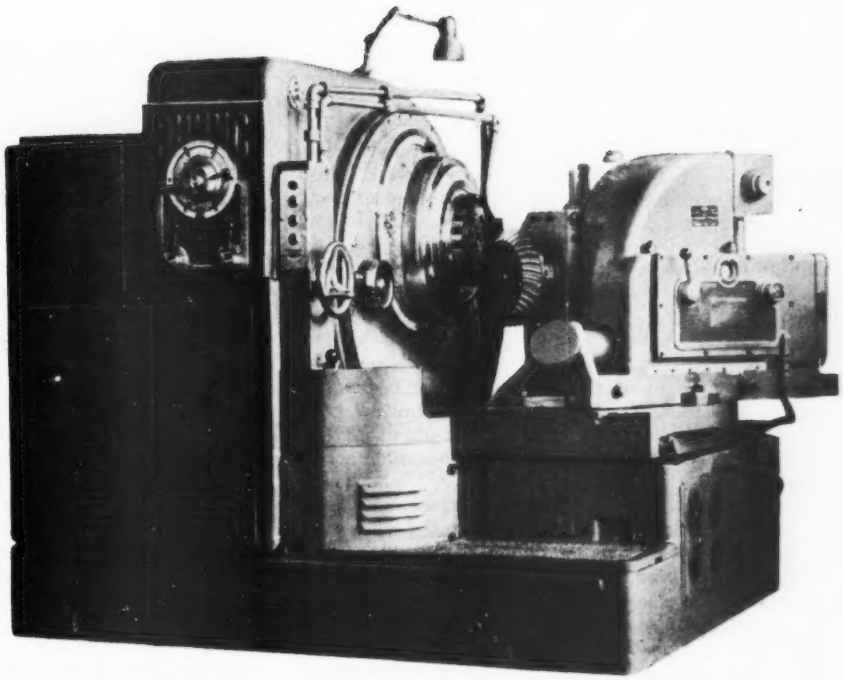


Fig. 1. Semi-automatic gear cutting machine designed by ENIMS, a machine tool research institute in Moscow. Gear dia: 30/800 mm; cutting speed: 30/300 m/min; time of tooth working: 12/240 sec; modulus: 3/15mm.

specific problems in isolation would be fruitless, and, like a man who steps back from a painting to see a detail in its context, have created establishments with broader but still practical terms of reference. Owing to this difference in emphasis, visitors to Russia have sometimes found themselves talking at cross purposes—when discussing cybernetics, for example, one party regarding it as a science, the other as a technique.

There are strictly three kinds of research establishments in the U.S.S.R.: first, those controlled by the Academy of Science; second, branch institutes which serve single industries; and third, laboratories attached to factories. In that order they range from the theoretical to the immediately practical, though all are concerned with technical research. The branch institutes are not only vehicles for original work, they are nerve centres for the collection and dissemination of information and ideas. They are also the effective organs of state industrial planning. Thus the role of ENIMS (Experimental Scientific Research Institute for Machine Tools) is "to guide the construction of machine tools throughout the Soviet Union".

It is also charged to maintain and raise standards of design; to gather together ideas and methods evolved in practical industry, to investigate them and select those deserving a wider application, and to publish and distribute the results of such studies throughout the machine-tool industry; to examine new developments in alien fields — electronics, chemistry, or hydraulics, for example — and to assess their potential application to machine-tool design or manufacture. ENIMS also attempts to minimise duplication of production and research and development work; to check the characteristics of foreign machine tools, either before purchase or to ensure that Soviet tools are not inferior; to propose engineering standards; and finally to submit to Gosplan, the State Planning Commission, suggested production norms in numbers, types and output of given factories. Some designs are also prepared by the institute (Fig. 1).

The Soviet attitude to automation is strongly affected by the emphasis on standardisation and rationalisation, the proliferation of research establishments concerned with control and automation and, most important, the existence of bodies like ENIMS, set up to correlate and co-ordinate the activities of factories over a wide area. These factors permit, indeed promote, a degree of automation impossible in Europe and America. The development of automatic data processing will confirm this difference. Academician P. Kapitsa, the celebrated Russian physicist who studied under Rutherford at Cambridge, agreed with me that central planning tended to be unwieldy and that only the American invention of automatic data processing had made the Soviet system workable — to paraphrase his comment.

Soviet preference for long-term rewards leads their industry to be producer dominated, whereas Western industry is dominated by the customer. Indeed, the Americans consider selling goods more important than making them, while the Russians often appear to have a sublime disregard for the end product. Thus, much Soviet equipment, though serviceable, is poorly finished (Fig. 2). In other words the Soviet designer will pay more attention to ease of manufacture and less to the utility of the manufactured article than does his Western counterpart. Since the Russian is more ready to adapt his product to the production process, mechanisation and large-scale automation would seem to be more acceptable in

the Soviet Union than in the West, where the fancy of the customer, be he capital-equipment purchaser or mere consumer, has to be given serious consideration.

Independence of the market favours the Russian engineer in other ways. When considering the introduction of automation, the Soviet manufacturer need take less account of fluctuations in the market; he has a norm to fulfil and problems of varying machine utilisation and changing lengths of production run do not arise. He knows what is wanted in advance, and if he floods the country with goods that nobody needs it is not his concern. He has done his job.

He is also not affected to the same degree by questions of manpower; although labour cannot be treated as a mere element in the production process, it can readily be transferred from factory to factory as the need arises. In the West, on the other hand, particularly with the increasing power of trade unions and the growth of employee shareholding, labour cannot be regarded as one of the variables in the production process but rather must be treated as a fixed asset. Nowadays there is little scope to alter a company's employee strength to meet a change in the market; adjustments must be made to other parameters, adjustments likely to be incompatible with large-scale automation. Similarly, the reallocation of labour which becomes necessary on the introduction of automatic production methods is harder to effect in a free society.

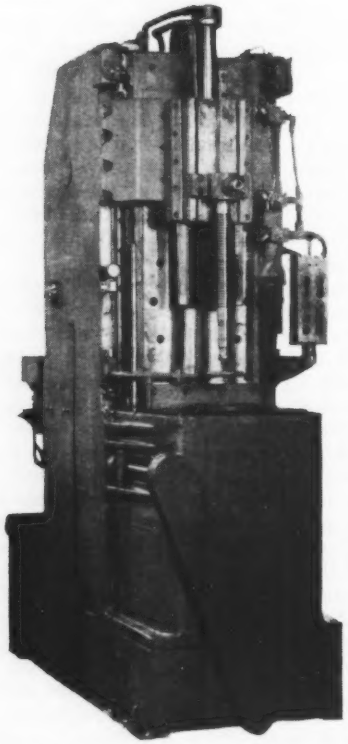


Fig. 2. Vertical broaching machine. Broaching effort: 20 tons; cutting speed: 10 m/min.

The human factor has certainly to be given greater weight in America and in the context of automation its influence is considerable. Attempts to make each man's job worthwhile and not a chore undertaken simply "for the money" have been legion. One such approach is known at IBM as "job extension".

The founder President of the Company, Thomas J. Watson, was walking round his factory when he noticed a girl standing by a machine which, like the girl, was idle. On being asked why she was waiting, the girl explained that the chargehand had yet to set up her machine. "Couldn't you do it?" inquired Watson. "Surely", replied the girl.

Following this experience, T. J. Watson had the work arranged so that as far as possible each operative should not only set up his own machine but test the product. The aim is "to make each man responsible for as many different assignments as possible." The trend in this case is counter to growing specialisation, though perhaps consistent with automation, where the routine jobs will be done by machines, and operatives will have the heavier responsibilities of control and maintenance.

"thickening of management"

Automation leads to a "thickening of management", since there is a general upgrading of all staff with the elimination of simple routine work, explaining perhaps why the Russians have trained far more engineers than they can usefully employ at present.

At ENIMS I was told that the shortage of unskilled labour in the Soviet Union made automation indispensable. Again, the Soviet planned economy with its greater mobility of labour and mass technical education encourages the growth of automatic production.

But automation introduces many other problems. Machines are not as flexible as people; they require more forward analysis, better forecasting, and more detailed consideration of initial location, since once sited they cannot readily be moved. It is perhaps because of these demands that (according to one of my American informants) productivity per man has actually been falling since the advent of automation.

The last distinguishing feature of a planned society that I propose to examine is its singleness of purpose. It is fairly clear that the central aim of current Soviet policy is economic supremacy. Mr. Khrushchev's disarmament proposals were not simply a diplomatic ploy, intended to disarm the West. Rather, they represented a consolidating measure. Division of Soviet resources between military and economic objectives were not acceptable. Evidently the Russians regard the economic arena as best adapted to their capabilities, in spite of occasional evidence to the contrary.

There are as many different objectives as there are people, in the West, where individual aims are expressed through the linkages of the price mechanism. Therefore, we cannot ultimately compete with Russia in the manufacture of capital goods,

because beyond a certain level of production capital goods serve none but a political purpose. We stand as much chance in this narrow kind of competition as the athlete who knits himself a pullover while running in a race. Divided attention does not make for victory. It is this situation that most determines the Russian attitude to automation.

effects of wealth

The second great distinguishing criterion is wealth. By wealth I do not mean the potential of a country, its natural resources, or the extent of its lands; I mean the actual, realised, exploited wealth that exists at the present time. It is the real wealth of the consumer, the abundance of his possessions and his capacity to enjoy them. In other words it is a nation's level of material development. By this definition, the West is already wealthy, while the East remains comparatively poor. I will illustrate the difference.

The Americans have come to take abundance so much for granted that they have, paradoxically, developed a marked indifference to property. The American will change his car or home with scarcely a second thought; whereas the Russian, who lives in a society where private property is anathema, treasures each small possession with sentimental attachment. I recognised the American disregard for private property in a story told me by John Diebold, the management consultant. I had twice left my shoes outside the door of my room in a New York hotel, but on neither occasion had they been cleaned. I mentioned this to Mr. Diebold over lunch at the Harvard Club. He said I was lucky. In Texas, where they were very rich indeed, an Englishman had put his shoes outside the door, and the chambermaid, thinking he had finished with them, just threw them away.

No Russian would throw away a good pair of shoes. The two Russian engineers who came to Britain as guests of *Engineering* following my own visit, first of all, on their arrival bought themselves new footwear.

It is apparent that the rate of capital accumulation in the United States — and probably in Britain too — is still greater than in Russia. It follows that where there is a choice between two or more production processes, the Americans will prefer one that is capital intensive to one that is labour intensive. Thus in the short term at least, the Americans will be inclined to favour automation, though other factors may offset this tendency.

Company and profits tax, for example, might, where onerous, serve to discourage heavy reinvestment. Taxation certainly affects the structure of industry; it may indirectly also influence the production process. Thus in France there is a turnover tax, such that any item is taxed each time it changes hands, so that a bought-out component for a motorcar, itself comprising other proprietary components, may carry several layers of tax. This system leads to a substantial measure of vertical integration; the Renault Company, for example, embraces most stages in motor car production, and production is highly mechanised.

But it should not be supposed that Soviet factories are unaffected by taxation or its equivalent. Effectively

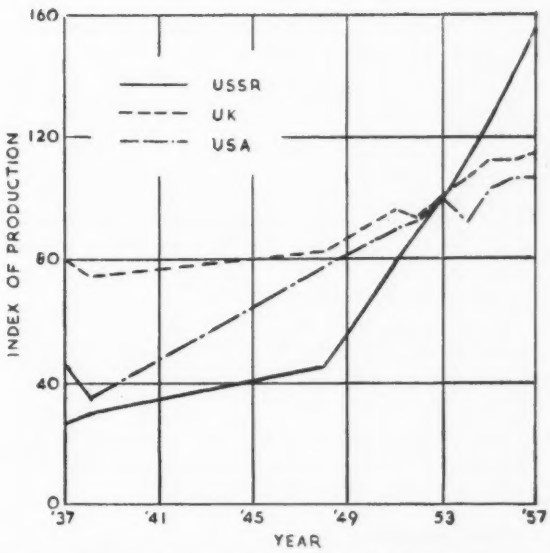


Fig. 3. Growth in the index of industrial production, expressed as a percentage of output in 1953 in the Soviet Union, United States and Britain. The graph is of course no indication of relative overall production or productivity (reproduced from The 1959 Sir Alfred Herbert Paper presented to the Institution of Production Engineers by Dr. D. F. Galloway, Director, P.E.R.A., and entitled: "Recent Production Developments in the Soviet Union")

the results are very similar. A factory is set a norm to fulfil, and to the extent that this requirement is exceeded, the management is permitted to plough back its "profits".

Except that conspicuous consumption is conspicuously avoided, there is no special reason for a higher rate of capital accretion in the Soviet Union than in the West.

Whatever remarkable achievements the Soviet Union has to its credit, it is still poor by Western standards. Although I was constantly escorted by an attractive interpreter, I do in fact understand Russian, and occasionally I picked up an unofficial observation. I was being escorted round the Moscow industrial exhibition and was taken inside a mock-up of a cabin for the atomic ice-breaker Lenin. At the window were a crowd of people, including a big tough-looking peasant woman. The guide turned to my interpreter and said: "This is a cabin for two sailors", and while the interpreter was going through the motions of translation, I heard the peasant woman cry: "For two sailors! We've got seven in a room like that."

Aware of this disparity in wealth, the East has deliberately chosen to pursue the West. Using the West as pacemaker and taking American living standards as its objective, the Soviet Union can plot its course with a certainty the West has never had. Whereas the Western manufacturer has had to probe and develop mass markets cautiously, or create them quickly by costly advertising campaigns, the Soviet industrialist is able to by-pass these preliminaries and

base his production schedules on American experience — often with curious results.

He can with little risk take short cuts to mass production, and stake considerable resources on large integrated production plants, knowing that he is moving in the right direction. It is because the trail of technical development is well cut that the Russians have had the confidence to devote the major part of their resources to capital equipment. The path to automation is made particularly easy for the Soviet engineer. He has no need to feel his way to the same extent as Western manufacturers.

At the same time, since he is trained to think in terms of definite objectives, he is likely to be better adapted to problem solving than to genuine invention. If he ever succeeds in overtaking his Western rivals, he will have to evolve a more creative outlook, to develop a sense of direction which at present he does not need. Or will he, like the greyhound that overtakes the hare, lose interest in the race?

market saturation

Another way of looking at the question of relative affluence is in terms of market saturation. For simplicity, regard the market as a tank and production as a stream of water pouring into it. In filling up the tank, there is no limit to the acceptable rate of flow (Fig. 3); but once the tank is full, the flow required merely to make up losses and maintain the water at a fixed level is comparatively small. I am aware that the parallel is naive, that new markets are continually being found, new tastes created for new kinds of product, that growing population brings fresh demands. But the saturation of particular markets by particular products is real, masked as it may be by other factors.

The rise and decline in demand for different products has always called for minor readjustments in the economy, often accompanied by temporary discomfort. But only recently have corporations grown to such enormous dimensions that the changing fortunes of a single concern may gravely disturb the economic balance of a nation. "What's good for General Motors is good for America." The converse is also true. A fluctuation in the demand for motor cars reacts on the steel industry, with repercussions throughout the whole economy.

It has been said that the closing of the American frontier was responsible indirectly for the Great Depression. When there were no new territories to settle and exploit, it became necessary to devise a more disciplined and less extravagant way of life, calling for agonising readjustments. A similar, though milder, readjustment may have been occasioned by the American consumer's discovery that he did not wish to go on buying new and bigger cars. Conceivably, this second encounter with the boundaries of a finite world has been a contributory factor in the latest trade recession. The present structure of demand, artificially expanded by high-pressure advertising, may well collapse into a new and denser equilibrium, as a giant start condenses into a white dwarf.

Signs of saturation are becoming apparent in the United States, but the Russians, like Thursday's child, still have far to go. Prodigal, even wasteful, production methods therefore continue to be acceptable in the Soviet Union, but the Americans have to carry out comprehensive market studies before undertaking large-scale manufacture. Even then, as in the case of the Ford Edsel, they may misjudge the situation.

In an unsaturated economy, it scarcely matters what you make or how many; the market is so vast that almost anything will find a customer. It is much more difficult in a saturated economy to make the optimum use of one's resources.

Demand is not insatiable, as the Americans have discovered. The American automobile lasts longer than was once supposed. Two cars are enough for most American families, especially when garaging, parking and road space are at a premium. No longer do people just get rid of things when they are tired of them.

If it were true that new outlets for energy and enterprise could always be found, why should a disproportionate technical effort be devoted to marginal refinements of certain consumer products and to the creation of transient and unpractical styling fashions?—Because an organisation economically tuned to the production of one basic commodity in large numbers cannot readily adapt itself either to producing new commodities or the same commodity on a smaller scale. Hence the need to maintain and expand demand for that one product. (Even the cost of retooling for changeover to a new model is beginning to present American automobile concerns with an almost insufferable financial burden.) Here lies a problem, a problem that now faces the United States and will one day likewise face the Soviet Union.

While I was in the United States, Mr. James Hagerty, President Eisenhower's Press Secretary, spoke to me in his office in the White House for about an hour. He made it clear that the American economy was undergoing certain readjustments, but assured me that it was sufficiently flexible to adapt to any new situation. It had always done before. But at that time, in 1958, things looked grim. The mood was perhaps summed up by a pasteboard inscription which I noticed on Mr. Hagerty's wall: "One day as I sat musing sad and lonely and without a friend, a voice came to me from out of the gloom saying, 'cheer up, things could be worse.' So I cheered up and sure enough, things got worse!"

Expansion in demand must gradually slow down asymptotically, until it just keeps pace with growing population. The underdeveloped countries are no answer to this problem, since American manufacturing economies are keyed to the prices that Americans are prepared to pay.

the changing economy

The next transition will be from a cumulative growth economy to a replacement economy. Already there are trends in this direction. The proportion of tyre retreads in America before the War was 10%; in 1948 it was 17%; and, in 1959, 33%. A vice-president of Westinghouse told me that demand for

refrigerators and television sets (though not for washing machines) was now largely confined to replacement items; initial installation accounted for a relatively small proportion. To allow for the diminution in demand, an original 35 manufacturers had contracted to roughly 10 — " those who can do it best or afford to do it longest ".

But the elimination of less successful businesses or their transfer to other products cannot provide the complete answer to the problem of replacement manufacture. In most cases, no doubt, replacement demand will not fall below the economic manufaturing capacity of a reduced number of plants, but the adjustment, should it be necessary on a considerable scale, may have widespread repercussions. Indeed, for certain products, the nature and capacity of production facilities will be determined by the estimated level of replacement, and no longer by the prospect of a rapidly expanding market. An artificially high level of production has been maintained in certain cases by "planned obsolescence", but it is unlikely that this device will be extended from styling changes and technical refinement to built-in technical deterioration — in spite of many opinions to the contrary. " They time those things," says Mr. Arthur Miller's deathless salesman, " They time them so when you finally paid for them, they're used up ".

Increasingly, production engineers in America will have to adapt their methods to a replacement economy — shorter production runs, tape-controlled machine tools, component repair. It is even conceivable that tools controlled directly from the drawing will be adapted to consumer-goods production. Cheaper tooling methods are likely to be developed. Where production is in large numbers, expensive tooling can be readily assimilated, but as numbers diminish, tooling will become more critical. Attention is likely to be devoted increasingly to this aspect of the production process, to spark erosion, electron beam milling, plasma-jet metal removal and similar techniques.

Producing in comparatively small numbers at low cost is not a new problem (according to a market consultant who discussed the matter with me, 80% of all hard goods made in the United States are produced in runs of 25 or less) but there are many consumer items that have never been examined from this point of view.

Because they have reached this point in the evolution of their market structure, the Americans are likely to be far more cautious than the Russians in introducing automation. Multiple-tool machines are likely to be preferred to completely integrated lines, transfer presses to transfer machines. One multiple-tool machine I saw described recently, was a turret broach. Continuous heat treatment plants will be installed, but seldom as components in integrated production lines, as is sometimes the case in Russia.

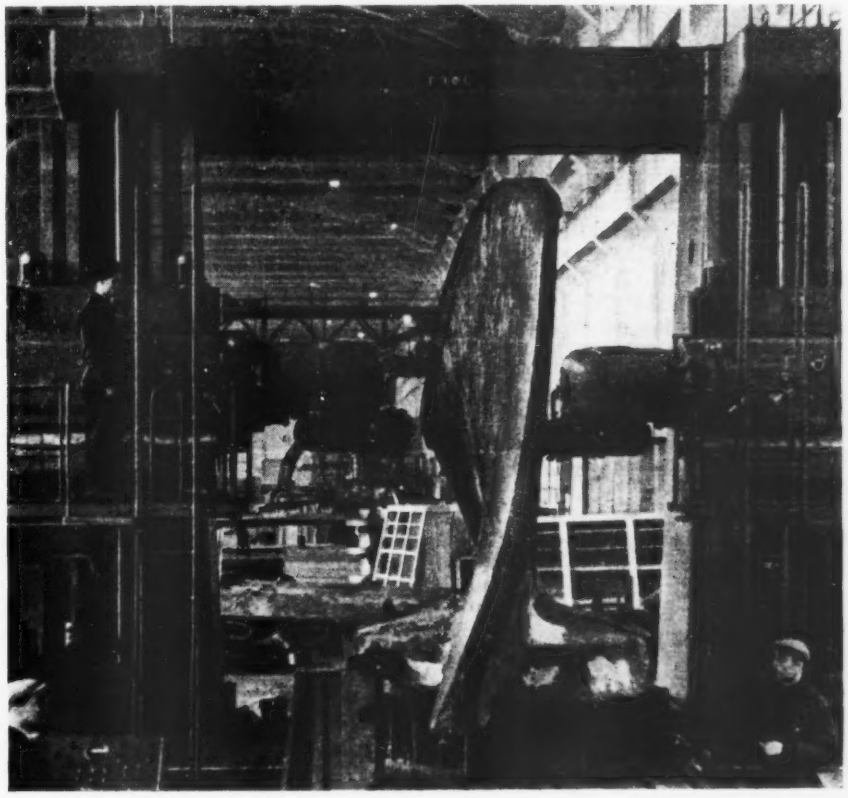


Fig. 4. Milling both faces of a Kaplan turbine blade simultaneously in the LMZ turbine works at Leningrad. Special purpose machine tools and large scale plant are characteristic of Soviet engineering practice.

Multiple-head spot welding machines are used in the fabrication of car bodies, but only where production is in enormous numbers can such machines be fully utilised.

Another approach to the same problem has been discussed by Mr. V. G. Raviolo, executive director, engineering staff, of the Ford Motor Company, Dearborn Michigan, in a recent talk to The Institution of Mechanical Engineers. The need for diversity, he said, presented the discriminating Western world with major engineering problems. Motor-car manufacturers must learn to produce interchangeable components in great volume and to make a variety of vehicles from these components. This procedure had been adopted in some degree, but more ingenuity would be required in the future. Internal body structures common to several car lines had been used by the Ford Company and their competitors, and also in England. But it was necessary to go much further with the mechanical components than had been attempted so far. The optimum range would be created by providing a series of shells, into which alternative power plants could be fitted. An approach of a similar kind has long been used by Rover in the United Kingdom. The concentration of substantially all the mechanical parts into power packages would permit a high degree of interchangeability without affecting basic body shells. Further, such power packages would not be affected as readily by styling change as conventional chassis were, with the result that a high degree of automation could be justified.

A similar technique has been adopted by the Lapointe Machine Tool Company, who have developed a broaching machine on the "building block" or unit construction principle, which enables the same basic machine to be used for long and short workpieces. The machine base is built up from a 40 ft. centre section and two 12 ft. end sections. If it becomes necessary to broach longer spars, only new sections would have to be added.

effects of scale

Britain's problems are different from those of both Russia and America. Britain inevitably operates on a smaller scale; her risks have to be more carefully calculated. Unlike America we cannot afford to squander our substance on doubtful projects; and unlike Russia we cannot assimilate big risks by the swings and roundabouts of central financing. As it is, we may suffer a severe blow when we find that a necessary larger scale capital investment — say in the mines — proves to have been based on false assumptions.

The scale on which Soviet engineers can operate, and also planning and market considerations, have led to certain striking developments both in design of tools and in production methods. Scale of demand makes it convenient to build large special-purpose tools such as the duplex milling machine which I saw in the LMZ factory in Leningrad, designed to mill both sides of Kaplan turbine blades simultaneously (Fig. 4).

Also, since there is (a) a large and (b) an unsatisfied market in the East, integrated production processes can be adopted without heavy risk. A big market favours automation, but the Russians do not yet appear to have discovered that the rapid conversion of a potential mass market into a real one by large-scale advertising is an economic prerequisite of mass production.

Professor Seymour Melman has described the large-scale production of standard machine-tool components, designed, incredibly, to fit together into a variety of machines like simple building bricks — machines for mass production, mass produced. I met Professor Melman when he was in London and he told me that the man-hours required to "mass produce" a certain machine tool had been reduced by this technique from 650 to 200.

Scale is also a dominating factor in the United States. I was told that if all the country's 45,000,000 television sets were switched on simultaneously, they would account for 15% of the nation's generating capacity. American corporations are large, comparable perhaps with national undertakings in the East.

Size has many advantages, for its weaknesses — unwieldiness, remoteness of control—can be offset by proper decentralisation. So far no one has determined the optimum size for a corporation, though the optimum size for production facilities devoted to particular products is clearly a different matter.

General Electric has a total of 280,000 employees, U.S. Steel has 230,000, Westinghouse 115,000, and du Pont 89,000 (du Pont's stockholders amount to twice this number). The military and civil capacity of Convair is said to be such that 80% of world civil-aircraft demand would keep it going for only 10 - 18 days annually. The size of the Plymouth automobile plant (1955) of the Chrysler Corporation is indicated in the Table below.

Quantities for Plymouth Automobile Plant (1955).

Plant area	1,229,184 sq. ft. ½ mile long, ¼ mile wide.
Employees	13,000
Output	2,150 cars per day 3,300 engines per day.
Conveyors	140 25 miles in total length
Machine tools	1,577
Power hand tools	1,200
Electric motors	4,993
Connected h.p.	14,000
Fork lift trucks	70
Material per day	300 lorry loads 80 railway truck loads 6,000,000 lb
Electrical consumption	3,310,000 kWh/month
Gas consumption	13,179,700 cu. ft/month
Steam consumption	37,710,000 lb/month
Water consumption	3,694,000 cu. ft/month

The largest Soviet plant I visited was ZIL, also devoted to vehicle production, which had 40,000 employees. The numbers of employees, including the proportion of engineers and technicians, at ZIL and other establishments is indicated in the Table opposite.

But Britain has to find other outlets for her enterprise; scale is not one of her advantages. Britain has a tradition of empiricism: we don't embrace a social philosophy like Russia or a way of life like the United States, we look at the facts and act accordingly, taking the best from everybody.

Russia and America, one through the state, the other through the big corporations, are creating

tightly woven systems, machinery that has to be kept going and maintained. Isaac Asimov in his novel: "The Caves of Steel", describes a city so populous, so mechanised, that a single administrative flaw or breakdown could stop the works and starve the city.

Complexity can be a form of slavery. The organisational demands of a society, the need to be at an office or an airport at a certain time, command the whole programme of the individual's life. The advent of computers and automatic data processing makes possible even greater complexity, and tends further to encourage the growth of integration. Kapitsa agreed that the planned integrated economy of the Soviet Union might have become unmanageable had the Americans not invented automatic data processing.

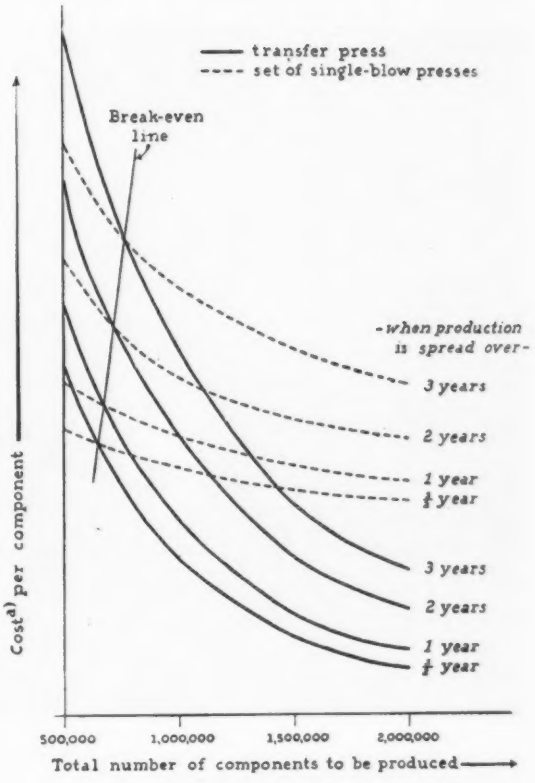
America and Russia have far to go before reaching a completely interlocked situation, but in their large-scale introduction of automation are they not making themselves less and less flexible, thereby exposing themselves to catastrophic instability? The American automobile industry may not have been responsible for the recession, but it certainly served as a resonant circuit to amplify the downturn.

Mechanisation has a special appeal to Americans. By a process not unlike flow-line production, I got my American visa in 20 minutes, as against three weeks for my Russian one. But mechanisation does not always work out. Dean Harrison of The Massachusetts Institute of Technology tells the following story:

He had been on his way to the West Coast, when, while taking a break at Chicago, a little old lady had approached him all atwitter, and asked him how to operate an automatic orange-juice dispenser. "I don't know how she knew I was from MIT," continued Dr. Harrison, "but I said, 'Madam, it's very simple! All you have to do is put a dime in the slot and the machine will do the rest.' So she opened up her reticule and fished around in it; finally she came out with a dime and put it in the slot, and the machine began to shake and quiver and the gears began to clank and lights flashed, and a big gulp of orange juice came out of the faucet and went straight down the sink. Then a paper cup fell into place."

If we must have automation, then let us make it work.

The U.S.A. has vast capital resources, the Soviet Union vast potential markets, both encouragements to introduce automation. But extensive automation tends to freeze an economy into a permanent mould.



[a] *Only those costs are included which vary differently for the different methods of manufacture.*

Fig. 5. Break-even points for transfer and single-blow presses (Bulletin of The Oxford Institute of Statistics, Vol. 21, 1959, p.131).

If a nation is to have automation on the largest scale it must be prepared to accept the same model year after year and greater uniformity.

Britain's opportunity seems to lie in her adaptability. Thus we should continue to introduce automation only as an *ad hoc*, piecemeal development — mechanisation rather than wholesale automation, which might become a liability. We must be prepared to accept pockets of primitive methods and forego the risks of large-scale pioneering. It is worth bearing in mind that even for a transfer press the break-even

Engineers and Technicians in Factories and Research Organisations

Organisation	Total employees	Engineers	Technicians and draughtsmen
Bearing factory	10,000	450 (4·5 per cent.)	
Special-steels plant	10,000	1,000 (10 per cent.) (including metallurgists)	
Turbine generator factory	11,500	1,000 (8·7 per cent.)	2,000 (17 per cent.)
Electrical generator factory	6,000	1,000 (17 per cent.)	2,000 (33 per cent.)
Machine-tool plant	2,500	300 (12 per cent.)	140 (5·6 per cent.)
Motor-vehicle factory	40,000	6,000 (15 per cent.)	
TSNIITMASH (heavy engineering research institute)	4,000	860 (21 per cent.)	—
ENIMS (machine-tool research institute)	2,450	850 (35 per cent.)	

It should be noted that the staffs for the two research institutes include workers in various associated plants. The figures given also include senior engineering qualifications—doctors and candidates of science, in addition to diploma engineers.

Fig. 6. Machine for continuous casting using facing link tracks on an incline at the Hammer and Sickle factory, Moscow.

point as against single-blow presses is in the region of a million components (Fig. 5).

The United Kingdom can certainly introduce areas of mechanisation — even for such purposes as sorting steel specifications — but on too large a scale it would be fatal.

Programme-controlled machines designed to produce small batches economically would appear to be more consistent with our situation than massive integrated production lines.

automation in practice

In that the Russians have special reasons to favour automation, it may be useful to take a closer look at Soviet production engineering, and in particular, the application of automatic methods.

Generally, the Russians are quick to take advantage of new ideas, and although, as I have suggested, they are, in many areas, still at the stage of problem solving and imitation rather than creative invention, they are certainly not without imagination. Recent Soviet machine tools are of unique design; efficient machinery exists for studying and putting into practice new techniques and processes.

I saw demonstrated at TSNIITMASH (the heavy industry research institute) a process whereby steel components as much as one square metre in cross section could be welded together. Academician E. O. Paton, who invented the "flux-bath" process, as it was called, had recently been invited to London in order to describe it. The Russians had independently developed an attractive method of continuous casting, on an incline, using facing link tracks (Fig. 6). I saw the machine and some of its products, and though they were not perfect, they were usable, and I gather that the technique has since been much improved. High-speed machining, ceramic cutting tools and modern methods of metal removal, such as spark erosion, have been extensively developed and applied.

Nothing is ever entirely new, but ideas which were fresh to me included the use of a magnetically susceptible powder in conjunction with an electromagnetic field to grip delicate items, such as piston rings, for machining; a vibrator applied to a large vertical boring machine to give a smooth finishing cut; the combination of high-frequency heating and ultrasonic methods to give rapid penetration in surface hardening; simultaneous broaching and heat treatment of special steels; the use of vacuum bells to enclose ladles of molten steel in order to remove dissolved gases more rapidly and cheaply than had hitherto been possible; and a simple device (Fig. 7) for checking horizontal surfaces by comparing liquid levels in two pots linked by flexible tubes. (The pots had micrometer adjustment and a second tube carried compensating air.)

Improvisation in factories is a commonplace. Apart from the production of special purpose tools by the ZIL automobile factory for their own use, I saw a neat and workmanlike machine (Fig. 8), designed and built at the Electrosila works, Leningrad, whereby generator windings were taped with insulation. Another machine had been devised for automatically fabricating mica insulation (Fig. 9). I was told that to perform this task automatically was extremely difficult, and it was the first such machine to prove successful.

Typical of the plant in use at the Hammer and Sickle metal works in Moscow was a UZTM four-high cold rolling mill, 1,300 mm. wide, with a working

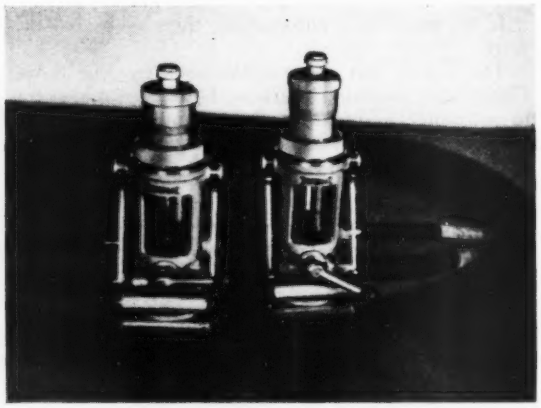


Fig. 7. Instrument for checking surface level over distances up to several metres. One tube carries the indicating fluid, while a second tube carries compensating air.

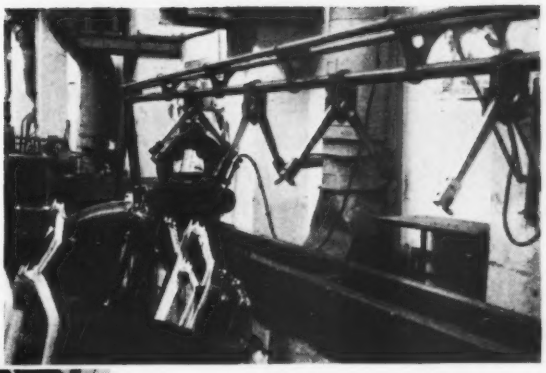


Fig. 8. (right). **Automatic machine for binding insulation on to generator windings. The series of double arms support the conductor and open in turn, allowing the rotary binding mechanism to pass along the carriage way.**

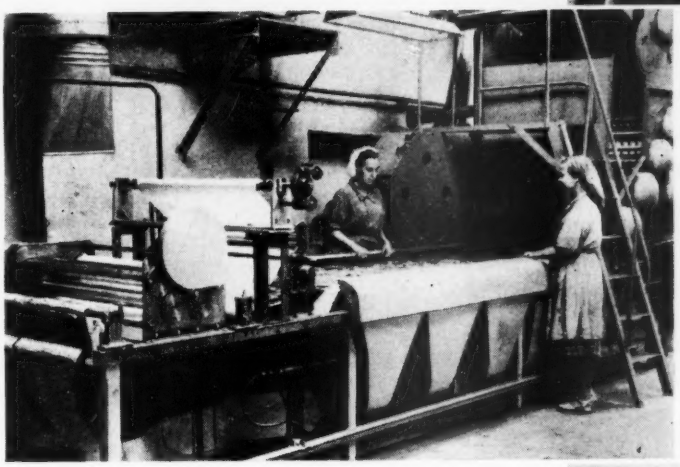


Fig. 9 (left). **Automatic machine for making mica insulation, designed and built at the Electrosila factory, Leningrad. The machine, which lifts the pieces of mica by vacuum and lays them between sheets of paper, is said to give uniform thickness.**

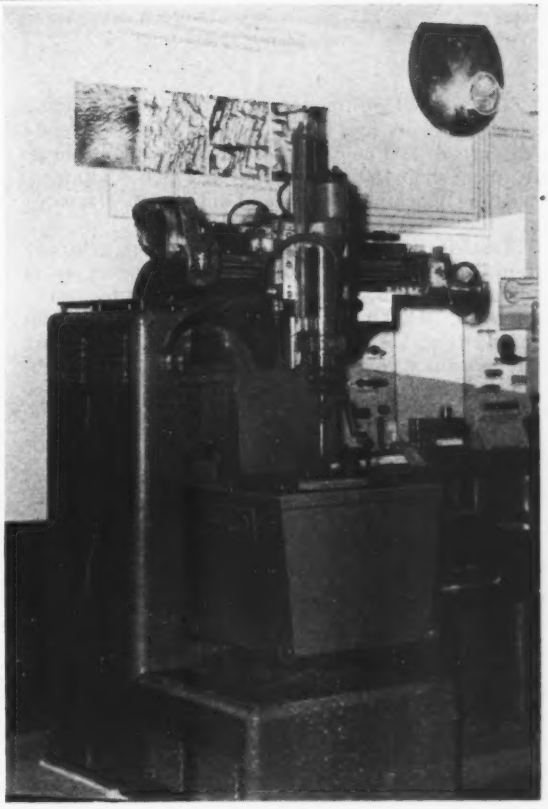


Fig. 10. (right). **Spark erosion machine designed for automatic copying and said to be capable of producing a complete piston in hard metal in 40-45 minutes.**

roll 375 mm. and a back roll 1,100 mm. in diameter. Elsewhere I saw a spark-erosion machine (Fig. 10) designed for automatic copying and said to be capable of producing a complete piston in hard metal in 40 - 45 minutes; tungsten dies could be made from copper patterns in some 10 - 15 minutes. Metallising spray techniques had also been developed. In an automatic balancing machine adjustments to the balance of a component were made automatically by electric sparking (Fig. 11).

At LMZ, an electro-induction copy milling machine made by a Gorky works (GZFS) was said to have reduced the time for producing a particular component from 1,500 to 100 hours; setting had previously been performed by hand. Punched-card profile millers are also made, while photo-electric, magnetic and punched paper tape techniques were under investigation.

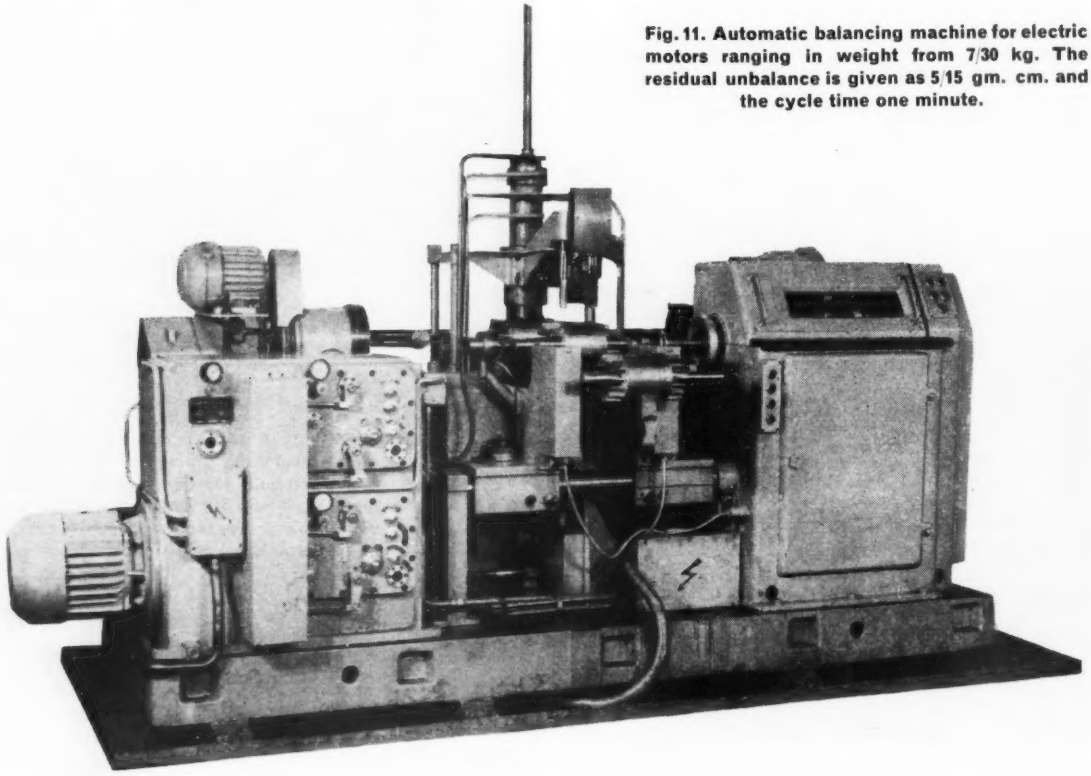


Fig. 11. Automatic balancing machine for electric motors ranging in weight from 7/30 kg. The residual unbalance is given as 5/15 gm. cm. and the cycle time one minute.

ZIL used high-frequency heating for welding vehicle radiators, and had a vast tool shop (employing two shifts of 800 men and served by a separate heat-treatment shop 150 metres long) in which equipment, including machine tools, was built for the factory's own use.

Methods of production and machines are generally up-to-date (Fig. 12); high-frequency heating is in common use for applying cutting-tool tips; semi-automatic machines are as common as in this country (Fig. 13); mechanisation and automation are playing an increasing part in production; high-cutting speeds are widely employed. The Table below has been taken from *Technical Progress in Machine-Tool Construction* by A. Prokopovich of ENIMS (the machine-tool research institute); it gives cutting speeds for different kinds of machine tool in various countries. The Table applies to 1955.

While I was in Russia there was a vigorous drive to minimise waste, and in particular to reduce the quantity of metal cuttings. One approach I saw was a cylindrical trepanning tool comprising a hollow steel cylinder over a metre long with four double-edged cutters arranged symmetrically around one end. The cutting edges projected inside and outside the cylinder. The cylinder could be gripped in the chuck of a large drill or vertical borer, and a drilling cut made up to one metre deep. In this way part of the

Average Cutting Speeds for Machine Tools (Presumably Working on Mild Steel) in Various Countries: According to A. Prokopovitch.

	U.S.S.R.		U.S.A.		U.K.		W. Germany	
	Metres per min.	Ft. per min.	Metres per min.	Ft. per min.	Metres per min.	Ft. per min.	Metres per min.	Ft. per min.
Centre lathes	400–600	1,310–1,970	525	1,720	450	1,480	550	1,800
Boring machines	300–500	980–1,640	200–600	660–1,970	—	—	450	1,480
Drilling machines	80–100	260–330	92	300	—	—	160	520
Grinding machines	35	110	35	110	30	100	35	110
Milling machines	400–500	1,310–1,640	400–500	1,310–1,640	—	—	370–470	1,210–1,540
Gear-cutting machines	40–50	130–160	40–50	130–160	60–150	200–490	80–160	260–520
Planing machines	50–75	160–250	91·5	300	61	200	—	—
External broaching	14	50	14·7–80	50–260	—	—	—	—
Internal broaching	11	40	15–18	50–60	—	—	—	—

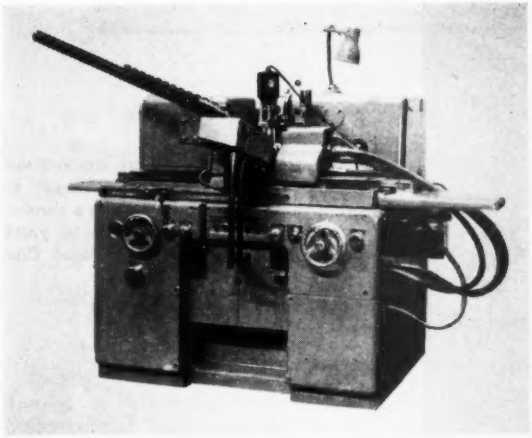


Fig. 14. Automatic cylindrical grinder. Range of grinding diameters: 10/40 mm; maximum width of ground workpiece: 60 mm; grinding wheel diameter 400 mm; range of workpiece speeds: 100/450 r.p.m.

waste material (a central cylindrical bar) was retained intact.

Economy of manufacture is a theme which Soviet production engineers take very much to heart. ENIMS, for example, keeps a close watch on production techniques, and formulates a policy to secure the maximum economy. Thus I was told that the "main purpose of machine tools was to make articles, not cuttings". Although this philosophy has long been accepted in the West, it has never been pursued on such a grand scale as in the Soviet Union. With this object a decrease in the number of universal lathes and an increase in grinding machines had been planned (Fig. 14).

In 1955, of the 98,000 production machine tools manufactured, 30% were universal lathes; by 1960 which only 20% would be universal lathes. The aim was to increase casting production—and hence grinding—and reduce wasteful metal-cutting procedures. With the same purpose, considerable attention was being devoted to welding development.

It is of interest that the production of lathes in the United Kingdom is just over one-quarter of total machine-tool production, though, excluding capstan and turret lathes the proportion is not as much as 15%. The United Kingdom production of grinding machines is probably about 10%.

Fig. 13. Semi-automatic turret lathe. Range of spindle speeds: 200/3,350 r.p.m.; maximum diameter of workpiece 25 mm.

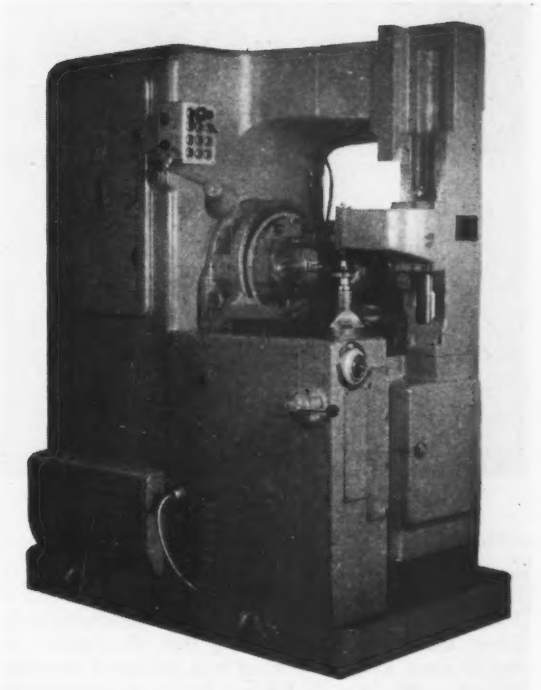


Fig. 12. Semi-automatic gear hobbing machine for cylindrical gears. Working diameter: 250mm; modulus: 5; speed up to 300 m/min; weight: 4,500kg.

But a comparison of East and West cannot be complete without some measurement of productivity. Unfortunately, satisfactory figures are not available. The British machine tool industry in 1956, employing nearly 46,000 men, produced 155,000 tons (deliveries) of equipment. The Soviet industry produced 250,000 tons (roughly 120,000 tools), with nearly four

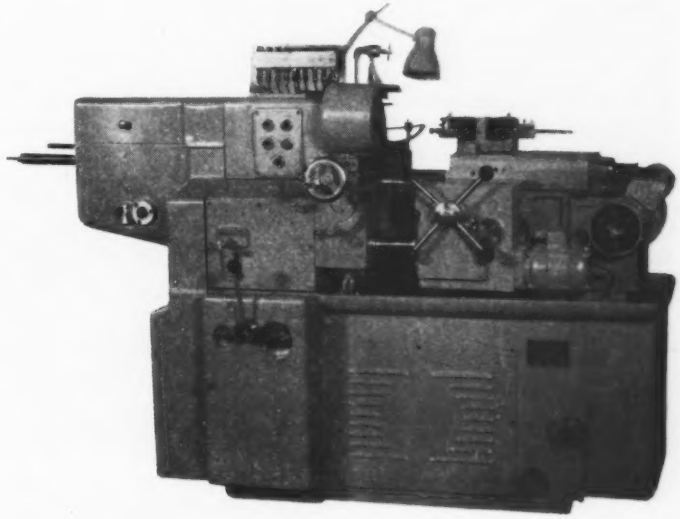


Fig. 15. Soviet factories are decked with banners designed to encourage the worker, and to promote in him a sense of community. The poster appeals to young workers to be tireless in building Communism.

times as many men — the Soviet machine-tool industry is said to have a trade union membership of 180,000. It would seem that Soviet productivity is lower than Britain's, assuming that the figures for employment and the types of tool produced are comparable. But the U.S.S.R. tends at present to concentrate on capital industry, leading presumably to a greater proportion of heavy machines (3% of total Soviet production comprises large units made to order). The emphasis on heavy tools would tend to show British productivity in an even better light.

Production methods depend to some extent on the handling of workpeople. The Soviet approach to work encouragement appears to combine two main elements. One aim is to promote a sense of community, and the other to provide realistic incentives.

use of slogans

Every Soviet factory I visited was scattered with slogans; every beam carried a banner or poster with a call to build Communism or to fulfil a quota (Fig. 15). There appeared to be certain grades of slogan, depending on the quality of labour employed. Thus whereas a manufacturing plant would display emotional appeals to patriotism, in the workshops of a research establishment a more rational approach might be adopted — "Increase output and raise living standards". I noticed that in only one workshop — where women were employed exclusively — was there a departure from the usual red poster; there they were blue.

Another method is to display photographs of efficient workers in a prominent position at the factory gate or the entrance to a workshop (Fig. 16). The number included on such a merit board would be between 20 and 100, sufficient to discourage the cynic from scoffing, in that his own face might appear at a later date, or at least his comrade's. Badges indicating good progress are occasionally worn and orders awarded for outstanding work — the Stakhanovite principle is well-known. I saw one workman wearing a badge inscribed "good worker" — in German. I was obviously not the first foreign "delegation" to visit the factory.

Community sense is further fostered by housing schemes, work clubs, holiday resorts, hospital and other free services, associated with particular factories. Such facilities must also discourage workers from changing their jobs. The ZIL factory even produces its own daily paper, of which some 25,000 - 30,000 copies are distributed each day. It is significant that most people are Consomol members (Young Communists) until they are 28, though roughly only one in 30 ever becomes a Party member.

And there are the pictures of national leaders, which appear in all entrance halls and offices; but whether the response to these was awe, fellow feeling, patriotism, irritation or indifference I could not tell.

Piecework is widespread. All workers at the GPZ ball-bearing factory were said to be on piecework, while 60% of those at the Sverdlov machine-tool factory and most of those at ZIL were also. Where piece rates are unpractical a progressive wage is established, as in an automatic flow line where tool setters are rewarded in inverse proportion to the number of bottlenecks in their section. Engineers, too, are awarded bonuses in accordance with the quality of their work.

Shift working as in other countries depends on the nature of the process. Thus at GPZ the automatic lathe and heat treatment shops are on three shifts, while flow-line, one-off, instrument and repair shops, including sections of the three-shift shops, are on two-shift working. Automatic lines at ZIL, however, are operated on three shifts.

Suggestions are rewarded under a complex but ingenious scheme. The following Table was copied from a notice board in the ZIL factory and recognises three grades of proposal: a simple rationalisation, a more complex idea and a fundamental invention. Awards comprise a percentage of the economy effected by the suggestion, plus a fixed sum.

Rewards for Inventions and Suggestions at the ZIL Motor Factory

Economy effected (roubles)	Awards		
	Fundamental invention (not less than 200 roubles)	Medium improvement (not less than 150 roubles)	Simple rationalisation (not less than 100 roubles)
Up to 1,000	30 per cent.	25 per cent.	12·5 per cent.
1,000 to 5,000	15 per cent. plus 100 roubles	12 per cent. plus 130 roubles	6 per cent. plus 65 roubles
5,000 „ 10,000	12 „ „ 250 „	8 „ „ 330 „	4 „ „ 170 „
10,000 „ 50,000	10 „ „ 450 „	5 „ „ 650 „	2·5 „ „ 350 „
50,000 „ 100,000	6 „ „ 2,500 „	3 „ „ 1,650 „	1·5 „ „ 850 „
100,000 „ 250,000	5 „ „ 3,500 „	2·5 „ „ 2,200 „	1·25 „ „ 1,100 „
250,000 „ 500,000	4 „ „ 6,000 „	2 „ „ 3,400 „	1 „ „ 1,700 „
500,000 „ 1,000,000	3 „ „ 11,000 „	1·5 „ „ 6,000 „	0·75 „ „ 3,000 „
Above million	2 „ „ 21,000 „	1 „ „ 11,000 „	„ „ 5,500 „
	but not more than 200,000 „	but not more than 100,000 „	but not more than 25,000 „

Finally, I noticed at one factory some workers dressed in what appeared to be highly coloured pyjamas, and was told that these men were sick and on "light duties". No doubt the conspicuousness of the costume serves to discourage malingerers.

Production must also be adapted to the premises in which it is pursued. Of the factories I visited only two had been built since the revolution: ZIL, an automobile plant (once ZIS in honour of Stalin, but since renamed) in 1924, and GPZ, the First State Ball-Bearing Factory, under the first five-year plan in 1932. The earlier factories, two of which are some 100 years old, are similar to factories of like age elsewhere, with shops added in largely haphazard manner as the need arose. The other two have been carefully planned, and are, therefore, of more interest.

GPZ — the First State Ball-Bearing Factory — is arranged about a straight spinal corridor 500 metres (1,600 ft.) long. The corridor is in fact double, an upper passageway for foot traffic, and a lower tarmacadam way for vehicles. Workshops are dis-

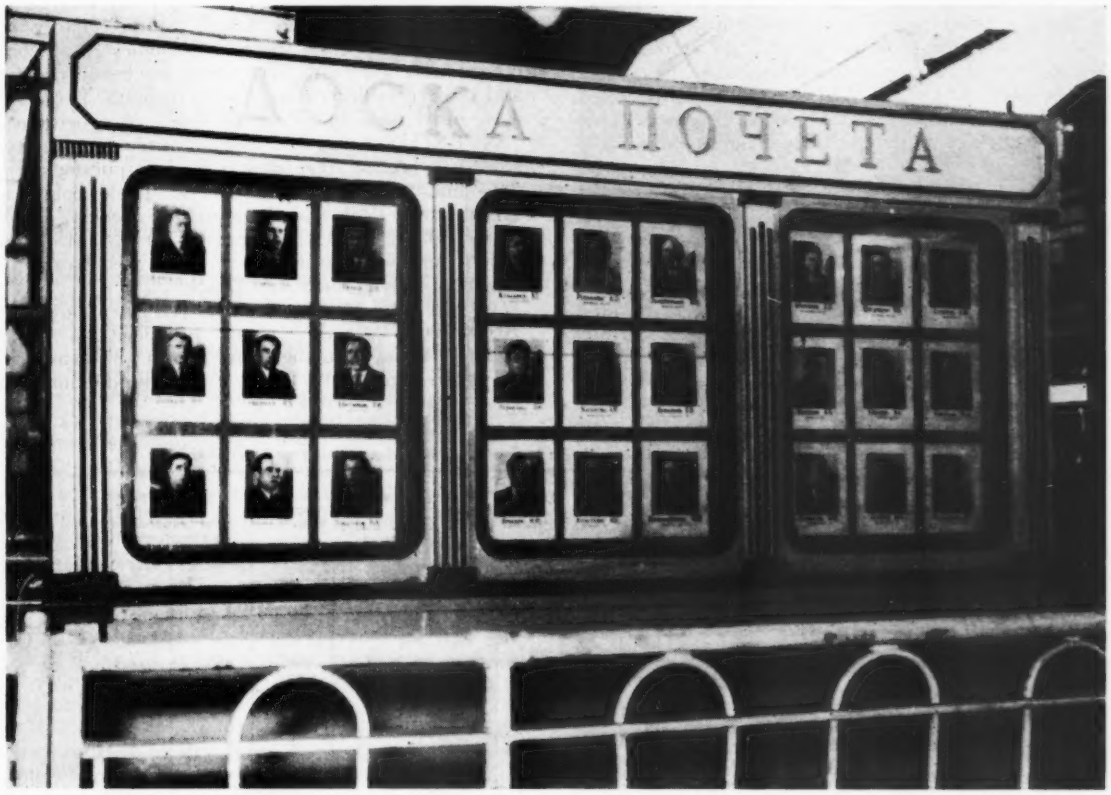


Fig. 16. Photographs of commended workers appear on honours boards placed in prominent positions at factory gates or the entrances to workshops.

tributed on both sides. Shops are clean and tidy, generally with wide lanes, though in some machine shops space between tools seems to be inadequate. A carefully planned factory of this kind would presumably offer greater scope for automation than one in which less attention has been paid to future expansion.

At ENIMS I had been told that the shortage of unskilled labour in the Soviet Union made the introduction of automatic production techniques an absolute necessity. At GPZ, for example, two aims were regarded as paramount: firstly, to minimise waste; and, secondly, to carry out a policy of gradual mechanisation.

All kinds of machine tool were checked at ENIMS for the possibility of programming, and complete flow lines were also being studied there—for machine tools as well as motor vehicles and tractors. Machine tool makers were also conscious of the need to design their products for possible use in automatic lines. Three kinds of lathe made at the Kransnie Proletarii factory in Moscow were fitted with special fixing points for transfer mechanisms. A prototype line was often built at ENIMS before being installed in a factory.

There are also several research organisations dedicated wholly to automation, including the Central Institute for Automation of the Ukraine, at Kiev, and a similar institute in Moscow. The Kiev institute is mainly concerned with heavy industry, such as chemical and metallurgical plants, and employs 700 people, but plans are in hand involving an increase in personnel up to 4,000. Other establishments visited by recent delegations to the Soviet Union include: The Institute of Automatics and Telemechanics, The Institute of Precision Mechanics and Computer Techniques, both in Moscow, The Institute of Electromechanics in Leningrad, and The Central Scientific Institute of Complex Automation in Moscow.

A party under Professor A. Tustin, of Imperial College, has reported work on the control of machine tools at three of the establishments visited. The Institute of Electromechanics has developed a computer for milling machine control. The machine approximates polynominal curves using digital differential analyser techniques to generate the polynominals from their differential equations.

At The Institute of Automation of the Ukraine, a turrent lathe had been converted to automatic operation from punched cards. Data transferred from the cards to a magnetic drum fitted to the lathe provided limit settings for the machining operation. Accuracy of turning was stated to be 0.05 mm. This work had been done in collaboration with the machine tool makers. The laboratory had also developed a special-purpose computer for converting design data to control instructions for a machine tool. The input was in the form of coded dimensions, punched by hand on tape from the drawing.

Research work into programmed machine tool control was also reported at The Institute of Electromechanics, where an automatically positioned drilling machine had been developed. The programme was punched on cards and the feedback of position was provided by an optical system; drive was by D.C. machines.

At The Institute of Automatics and Telemechanics a system of automatic control on cold reduction tandem mills had been proposed for a four-stand mill, and its design and performance studied with the assistance of an electronic analogue of the last three stands. Research on control techniques was being pursued vigorously, though not only for automatic production; thus at the LMZ turbine factory in Leningrad there was a special cybernetics group concerned with automatic regulation, electronic control and kindred subjects as applied to turbines. There are even institutes devoted to the study of cybernetics.

At ENIMS I was told that an automatic quality-control or check stage should be incorporated in a flow line wherever possible. The Table below is taken from *Technical Progress in Machine Tool Construction*, by A. Prokopovich, of ENIMS, and shows improvements effected by the installation of four flow lines in the Soviet Union.

At the ball-bearing factory (GPZ) a total of 70,000,000 bearings were produced a year (240,000 a day) ranging from 30 mm. - 1800 mm. in diameter, some 1,000 types in all. Production was

Improvements in Output Effected by Linking Machine Tools into Automatic Flow Lines in Four Soviet Plants

Automatic line	Annual output per employee (items)		Annual output per productive worker (items)		Output per square metre of floor space		Cost per component (Roubles) (less reduction in materials costs)	
	Before installation of line	After	Before	After	Before	After	Before	After
Line for machining cylinder blocks of motor combine U5-M, at the factory "Hammer and Sickle" ..	1,000	11,700 (11·7 times)	1,125	28,400 (25·2 times)	67	87 (1·32 times)	43·87	28·95 (36 per cent.)
Two lines for machining cylinder blocks of Diesel tractor DT-65 at the Kharkov Tractor Factory ..	825	7,190 (8·7 times)	1,040	10,790 (10·3 times)	69	160 (2·3 times)	200	161·6 (24·5 per cent.)
Three lines for machining cylinder blocks of the automobile "Moskvich" at the Low Engine Capacity Motor Factory	3,354	7,270 (2·1 times)	3,963	10,900 (2·7 times)	110	208 (1·8 times)	8·07	6·78 (16 per cent.)
Four lines for machining cylinder blocks of the ZIL-150 at the Factory I. A Likhacheva (ZIL) ..	3,000	5,800 (1·9 times)	3,580	8,700 (2·4 times)	196	265 (1·3 times)	9·77	7·50 (23 per cent.)

divided into two sections: mass production of standard components and also complete bearings where these were required in large numbers; and one-off or small-number production. The first of these sections was adapted to automatic methods, and there was, in fact, one completely automatic shop, with two flow lines (Fig. 17), one for spherical and the other for conical bearings. No other bearing factory in the Soviet Union had at the time of my visit in 1957 a fully automatic line. The general policy was to introduce completely automatic processes where possible, but otherwise to use old equipment and insert automatic sections as the opportunity arose, beginning with single tools.

A description of the GPZ automatic lines is as follows. Rough forgings for the bearing races entered the shop and were finished in a series of machines linked by conveyors. Balls initially produced from bar by a rolling process were also finished. Items were prepared for hot working by high frequency heating and were subsequently weighed automatically. In between major sections of the automatic line were large through-flow storage chambers (Fig. 18), to compensate for fluctuations in speed, and gravity transfer is used wherever possible. The flow line included a heat treatment section where, after heating, the components were quenched in a bath at – 70°C, using freon refrigeration.

On completion of the process, the items were cleaned and checked automatically, automatically assembled and checked again. Final cleaning, oiling and packing were also carried out automatically, the inner and outer races being packed separately. The output of one line was 180 bearings an hour. As a measure of the extent to which the lines were automatic, it should be noted that there were 35 setters for the two lines and 10 - 15 women responsible for size control.

Motor vehicle production is well adapted to flow line methods and at ZIL there were several scores of automatic lines. I saw the usual assembly line, in this case for ZIL-150 95 h.p. 4-ton trucks, and at strategic points overhead — and also in the controller's and despatcher's offices — there were display panels where red bulbs lit up to indicate points in the line where there was a stoppage. Each 3.5 - 3.8 minutes a truck would be completed, and subsequently received a 40-minute test.

The same factory made refrigerators and bicycles, the production of the latter being at a rate of two a minute. ZIL had a modern foundry, also operated on the flow line principle, with a conveyor 20 km. long and a considerable range of automatic moulding machines. The operator responsible for pouring metal into moulds was himself carried on a moving belt.

A light car factory in Moscow, where the type 407 45 h.p. Moskvich sedan is made, is reported to have an output of 210 cars per eight-hour shift, with a productivity rating of 230 man-hours per car.

Of about 200 automatic production lines which were operated in the U.S.S.R. at the beginning of 1959, 64, including several lines for the manufacture of nuts and bolts and hook chains, were run by the farming machine industry. The Altaisel'mash works

Fig. 17. Beginning of an automatic flow line for the production of ball bearings at the First State Bearing Factory (GPZ), Moscow. The process includes heat treatment, checking and packing. A tidy shop is graced by an occasional aspidistra.

Fig. 18. Through-flow storage chamber to compensate for speed fluctuations in one of the GPZ flow lines. Gravity feed is used wherever possible.

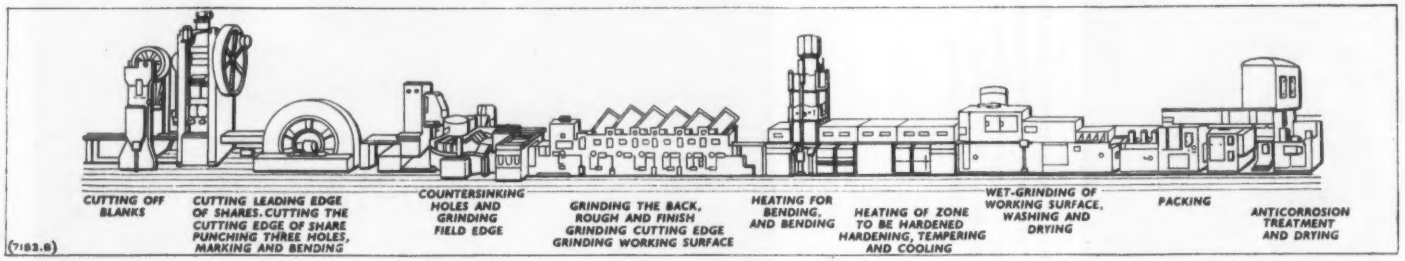

CUTTING OFF BLANKS
CUTTING LEADING EDGE OF SHARES. CUTTING THE CUTTING EDGE OF SHARE PUNCHING THREE HOLES, MARKING AND BENDING
COUNTERSINKING HOLES AND GRINDING FIELD EDGE
GRINDING THE BACK, ROUGH AND FINISH GRINDING CUTTING EDGE GRINDING WORKING SURFACE
HEATING FOR BENDING, AND BENDING
HEATING OF ZONE TO BE HARDENED HARDENING, TEMPERING AND COOLING
WET-GRINDING OF WORKING SURFACE, WASHING AND DRYING
PACKING
ANTICORROSION TREATMENT AND DRYING
(7183.B)

Fig. 19. Automatic production line for making plough-shares.

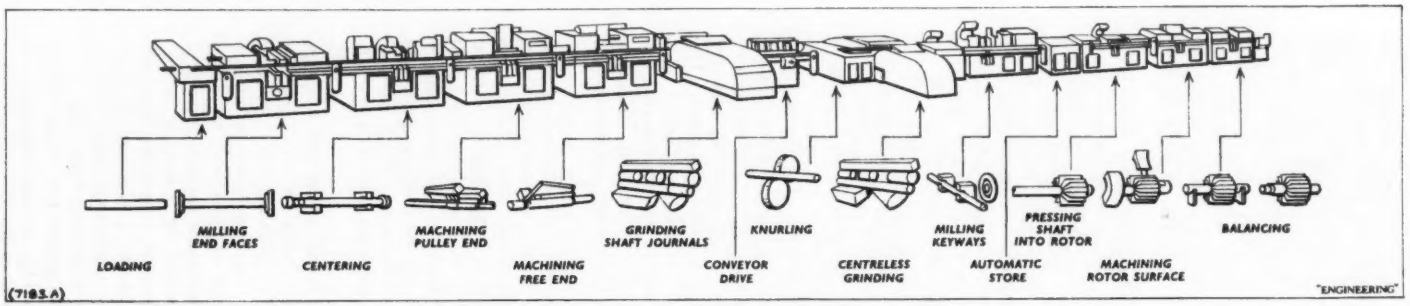


Fig. 21. Automatic line for producing electric motor rotor shafts.

(Figs. 19 and 21 are reproduced by courtesy of "Engineering")

operate three automatic lines: two for the manufacture of plough shares (Fig. 19) and one for mouldboards. The first line has an annual output of 1.1 million shares. Presumably, now that disarmament is in the air, swords are fed in at one end and ploughshares come out at the other.

The line uses a special rolled section as material, and is divided as follows:

1. cutting-off, cutting to size and stamping;
2. machining section where three holes are countersunk, the back cut and the working surface ground;
3. bending and heat treatment section in which the components are heated by high frequency current and electrically tempered;
4. wet-grinding, washing and drying section; and
5. finishing and packing section, where the shares are greased and bound with wire into lots of five.

The total power of the drive motors of two lines is 2,536 kW and they occupy a floor area of 864 sq. m. Novel features of the plant are reported to include devices for automatic grinding, for heat treatment and for handling and packing the awkwardly shaped ploughshares. Twelve men are needed to attend two lines. The installation of the plant is said to have increased the productivity of labour 3.7 times and halved the production costs.

As evidence of the extent to which automatic methods have been introduced, even in the manufacture of machine tools, the productivity of two Soviet factories may be compared. At the Krasnie Proletarii factory in Moscow, which employs 5,000 people, 900 - 1,000 standard lathes are produced monthly, plus 30 - 40 special machines*. With 2,500 employees the Sverdlov factory, in Leningrad, produces only 500 or 600 a year but 60% are special purpose tools†. It is evident that at the Moscow factory, where standard tools predominate, automatic processes must be extensively employed. It is reported that the factory makes wide use of unit construction, mass-producing components common to several different kinds of tool.

Of some importance is a variation of the unit principle known as "group machining". If a group of components are broadly similar in size and configuration, their common features may be combined to form a single composite component. This component may or may not be hypothetical. The production tool can then be set up to machine this composite component and hence, with only minor adjustments, the entire group. Thus the tooling may be written off over one long production run instead of several comparatively short batches. For example, 12 bushings may be combined to form a single complex bush (Fig. 20). Changeover from one bush to another would involve only simple adjustments.

* Dr. D. F. Galloway, "Recent Production Developments in the Soviet Union", *Institution of Production Engineers*, 1959.

† *Engineering*, vol. 184, page 409, 1957.

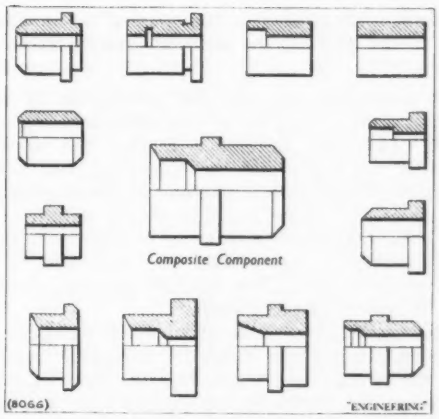


Fig. 20. The common features of several components may be combined in a single hypothetical composite component, thereby making possible a longer production run. *(Reproduced by courtesy of "Engineering")*

Success in this approach depends on the ingenuity of designers and production engineers. It is reported that the Leningrad Metal Works have compiled 180 group sheets representing 900 component types, with further classification for various sizes. Another factory divided 1,402 components into 138 groups with from 3 - 40 components per group. Tooling costs were said to have been reduced from 725,000 to 102,000 roubles (£65,000 to £9,000) using this technique. Over half the savings arose from the reduced cost of automatic lathe cams. The same principle has been applied to milling, grinding, diecasting and even electroplating. Soviet interest in this system is a further indication of that country's determination to increase the length of production runs to a point at which automation becomes feasible.

Even in Russia there are serious obstacles to the introduction of automation. Writing in *Engineering* (vol. 189, page 90, 1960), O. Tedder has suggested that high design and construction costs of automatic lines intended for the production of single articles are prohibitive. Thus actual lines are so designed that they may be readily adapted for the manufacture of similar components, differing slightly in design and size, which are used in large quantities in the engineering industries, such as gears, shafts, sleeves and bearing balls. Lines of this kind comprise standard automatic machines or general purpose machines linked by suitable transfer devices.

Automatic production lines for the manufacture and assembly of electric motor rotor shafts (Fig. 21) and spline shafts show how these problems have been tackled. The motor-shaft line consists of standard machines which can be used in automatic lines as well as in normal production. It is divided into two sections by an automatic store. A rest-and-run conveyor runs in front of the machines, and the components are taken from it by single-grip transfer heads. An automatic balancing unit detects and measures the unbalance and corrects it by drilling a hole of suitable depth. It is claimed that in one case,

the installation of such a line enabled the machining cost of the shaft to be reduced from 6.55 to 2.56 roubles.

An automatic line for the production of spline shafts is similar in layout to that manufacturing motor shafts. The only difference is that the units for knurling the shaft, and the balancing unit, are replaced by a high-output machine for the simultaneous cutting of all the splines. The yearly output of this line is 240,000 shafts and it can produce components of 13 different types. The line can also be run economically on smaller batches involving between 10 - 12 retoolings per month.

The use in these lines of two-grip transfer units, with separate transfer heads for unloading and loading the work, make possible an overlapping of handling and machining operations with a resulting economy in the total cycle time.

In the introduction of automation the Russians are said to suffer from certain handicaps. In Dudintsev's book, *Not by Bread Alone*, the inventor of an automatic machine for making drainpipes by centrifugal casting meets long and bitter opposition. If the book presents a fair picture, then it would appear that managers in the Soviet Union are often reluctant to make innovations involving risks not compensated by personal advantages. The service life of electronic and hydraulic equipment is reported to be short and reliability inadequate. Labour costs are comparatively low; so one of the major motives for introducing automation is lacking. Finally, the need to build automatic lines so that they may be adapted to produce a variety of similar items and to confine such lines to the manufacture of universal components such as shafts and sleeves shows that even the Soviet Union is affected by scale factors.

In present economic circumstances, human populations are only marginally sufficient to justify large-scale automation, and then only in the case of a limited class of articles. But with a population of 200,000,000, the Soviet Union is likely to break even before the U.S.A. with 180,000,000 and Britain (neglecting any European association) with 50,000,000. What is more, the Soviet Union has the great hinterland of China (600,000,000) and for political reasons may be prepared to sell manufactured goods in great quantities to underdeveloped countries at uneconomic prices. It is also in a position to advise the customer — as Henry Ford may once have wished to do — that he can have a car of any colour — so long as it is black.

what it means to Britain

My arguments, if they are valid, lead to a number of conclusions. The most promising line of development for the United Kingdom is the versatile multi-purpose tool and, in particular, machines that simplify and cheapen those processes that fall between the design concept and the cutting operation. Electronically controlled devices capable of translating a simplified engineering drawing into a finished product, eliminating the intermediary of labour, are a step in this direction.

Automation, inasmuch as it means the application of control engineering to production processes, is a word that covers a complex of ideas, and has led to a confusion of two quite separate principles. Producing identical products in enormous numbers requires the application of control engineering to ensure the steady automatic flow of items through a continuous process. Producing small numbers of widely differing components also calls for the techniques of control engineering as in the Ferranti and E.M.I. electronically controlled milling machines. But in terms of application one process is the converse of the other. It is the second, the production of variety in comparatively small numbers, on which Britain should concentrate her attention.

I do not suggest that Britain should neglect the techniques of mass production. At present there are large potential markets overseas for mass-produced goods, and there are many products that even in Britain are required in sufficient quantity to justify flow line methods. But we should bear in mind the advantage that Russia, America and even a united Europe will have in satisfying these requirements.

If we are to enter this particular arena we should find an approach appropriate to our situation, a role complementary to those of our massive competitors. We should also take care to distinguish between flow line methods in which human hands and minds play a direct part and completely automatic lines.

more standardisation

Britain should be quick to recognise techniques that help to minimise the disadvantage of a comparatively restricted market. We should be prepared to suffer greater standardisation in our manufacturing equipment, and where unit construction is possible, such that individual components are common to a variety of different assemblies, we should consider using it. Even machine tools might be susceptible to this treatment—several types of tool being based on a single set of building bricks, with the number of parts unique to each type kept to a minimum. An important variation of the unit principle involves the combination of several similar components in a single hypothetical component. Tools are then set up to machine the hypothetical composite component, thus permitting longer production runs. Similarly by rationalising stores procedure, the same component may be found to serve a greater variety of purposes, once more leading to longer production runs and cheaper manufacture.

Since we cannot increase our scale in size or numbers, we should perhaps attempt to do so in duration. The annual report creates a rhythm which is totally out of register with the frequency of modern engineering. Investment cycle should be adjusted to a longer wave length. Five-year plans are already familiar overseas.

Britain should also draw back further from the ultimate manufacturing process. A smaller fraction of our efforts should be devoted to consumer goods. We should first make tools for making tools; and later, tools for making tools for making tools, since at each withdrawal, the number of tools diminishes, as in

successive generations of a family tree, and Britain is likely to excel where numbers are small and technical content high.

It has long been recognised that Britain's export capability must increasingly depend on her capacity to keep an intellectual step ahead of foreign customers. The technical content per unit mass of her production must continuously increase. It is Britain's role to embody in her products the quintessential distillate of know-how. But know-how may be embodied in the production process as much as in the product. We may, for example, produce simple centre lathes, but produce them with such ingenuity that no rival can compete with us on price.

Nevertheless, in general, Britain should devote her attention to processes that favour production in comparatively small numbers.

Not only in Britain, but also in Russia and America, complete automation is only marginally economic for a limited number of products or components. Even in the case of simple items, it takes about a million units before a transfer press breaks even with a series of single-blow machines.

Though high at present, labour costs as a fraction of the overall production costs will have to rise substantially before the situation changes. Alternatively, population must grow sufficiently to create the larger markets without which fully automatic processes cannot be justified; or nations must sacrifice their economic sovereignty to achieve the same effect.

Extensive rationalisation will have to be undertaken, not only in stores procedures for a single company, but over many companies; universal moduli will have to be adopted for other parts than nuts and bolts. Standard shafts, gears, bearings, pulleys, even engines will be necessary; the concept of the packaged automotive power unit common to a variety of different cars will be extended into other fields; unit construction will be widely adopted until the raw materials of engineering become one vast Meccano set.

No doubt this extraordinary prospect will never materialise in full, but if automation is to come about on any appreciable scale, there must be far more simplification, standardisation and integration. It will mean a complete reorientation of our way of living. No longer shall we lay great store by material possessions; we shall take them all for granted. We shall not be disturbed by the knowledge that our cars, our television sets, our houses, cookers and refrigerators are identical with everybody else's, providing they fulfil their purpose; we shall hardly be aware of it. The richness of our life, variety, complexity, fulfilment, will stem from other sources. We shall feel nothing but contempt for predecessors whose petty pleasures revolved around a motor car; no more do we today cherish our indoor plumbing, or regret that drinking water has a universal flavour.

But all this is not yet. For the foreseeable future my conclusion is that the highest degree of mechanisation will be introduced in the Soviet Union, with America next, and the United Kingdom last. But we need not be concerned. Britain has a different part to play.

Well, after all that, I feel rather as I did when I was entertained at a party on my last night in Moscow. There were 15 Russians and me.

Every so often one of them would stand up to propose some irresistible toast like "Peace", "Your Queen" or "Mr. Khrushchev". It is necessary to drain the tumbler of Vodka in one gulp, otherwise it is an offence to the subject of the toast. After three or four, I decided that it was now my turn, so I leapt up and in my best Russian pronounced: "To The Institute of Heavy Industry" — an establishment we had visited that afternoon.

Unfortunately, I confused the words for "heavy" and "jolly", adding one more indiscretion to the tale of international misunderstanding. Maybe, then, as in giving this Paper, I should have followed the advice I saw written on a New York telephone: "Plug in brain before starting mouth".

The author of this Paper, who recently joined Martech Consultants, Limited, as a Senior Consultant, is a graduate of Cambridge University, where he took an honours degree in Mechanical Sciences. After completing a graduate apprenticeship with APV Limited, he spent a short period working on the Owen Falls Hydroelectric Scheme in Uganda. In 1953 he joined the staff of *Engineering*, where he remained for over seven years, being appointed a Deputy Editor and subsequently a Director.

During Mr. Ward's Army service, when he received an infantry commission and qualified as a parachutist, he completed a course in Russian and this was later useful to him when in 1957, on behalf of *Engineering*, he visited Russia to gather impressions on the quality of Soviet engineering. He was fortunate enough to be in Russia on the eve of the launching of Sputnik I, and interviewed P. I. Kapitza, the famous Russian physicist, said to be closely connected with the project. Mr. Ward later toured the United States in an attempt to judge how America was responding technically to the new Soviet challenge.

MODELS IN MACHINE TOOL DESIGN

by R. H. THORNLEY, M.Sc.Tech., G.I.Mech.E., Grad.I.Prod.E.

Mr. Thornley received his education as a part-time student at The Manchester College of Technology, whilst working as a designer draughtsman at Craven Brothers (Manchester) Ltd.

In 1956 he joined the N.R.D.C. Machine Tool Research Project (now supported by D.S.I.R.) at The Manchester College of Science and Technology, where he was awarded the degree of Master of Technical Science, on the strength of his research work.

THE shape and dimensional accuracies of a workpiece produced on a machine tool depends, amongst other features, upon the precision with which the various moving parts of the machine are guided. Any deformation of the guiding devices, slideways, oil films, etc., results in deviations from the required path and inaccuracies of the finished product.

Present-day demands for higher production rates can be met by applying heavier cuts and by increasing operational speeds. The former results in higher cutting forces and therefore greater loads on the various members of the machine; the latter, in increased operational frequencies. High static stiffness to reduce deflections under the heavy loads applied to the structure and dynamic stiffness to prevent resonance vibrations under the high working frequencies must be provided, as otherwise neither the dimensional accuracy, the required shape or the prescribed surface quality of the product, can be obtained.

For the overall stiffness of the machine frame to have a high value the stiffness of the individual elements must be very carefully chosen. It is also desirable that all the elements should, if possible, have matching stiffness, the reason being that the overall stiffness is not the direct sum of the individual stiffnesses, but the sum of the reciprocals of the individual elements, as in a series spring system. It is,

therefore, the element with the lowest stiffness and greatest deviation from the average stiffness which governs the final design.

The comparative stiffness of single elements can be used as a criterion of good design. The stiffness of the elements can be described by the following mathematically expressed terms:

(1) the stiffness against bending;
(2) the stiffness against torsion;
(3) the natural frequency of the first mode of dynamic deformation.

For the majority of machine tool structures, calculation of the above quantities is a difficult operation and investigation by experiment on finished machine tools is a costly and time-taking process. However, with the aid of model mechanics, models of geometric similarity can be investigated both statically and dynamically, and much more economically than full-size machine tools. With the help of the rules of mechanical similarity, it is possible not only to interpret the results of model tests and to predict what will happen to the actual design, but also to study the stiffness characteristics of several different designs, and from the results decide on the most satisfactory one. It is also possible to alter a design and after modifying or manufacturing a new model to re-test the model and so improve the finished product. To do this on a finished machine tool would involve a great deal of work and expense.

The effect of holes and bosses in a structure, also the positioning of securing screw holes, can easily be examined by model analysis, and the effect on the final structure estimated to quite fine limits (Opitz[1]).

Most machine tool elements can be represented by a combination of basic beams, the design of which may, however, differ considerably. Apart from the actual geometric dimensions, materials and manufacturing process, a beam obtains its stiffness from the nature of the design. Again, by the use of models of geometric similarity and the aid of model mechanics, it is possible to investigate both the static and dynamic stiffness characteristics of various beam configurations and evaluate the results to predict actual conditions.

theory of model mechanics

To apply the technique of model testing effectively to a problem, it is not only necessary that geometric similarity in both the original and the model is achieved, but also that the appropriate law of similarity must be observed for the loading concerned. Assuming that this is possible, the problem of translating the test results obtained from the model to the full-scale conditions must be solved. It is, therefore, necessary to establish relationships between the characteristics of the model and the actual structure.

Stiffness, deformation, stability and vibrations are factors considered in engineering design. Theoretical and test investigations must, consequently, aim at determining one or more of these parameters. It follows that a general solution of the problem consists of a number of expressions, each specifying the interrelationship between model and actual structure for a particular parameter.

scale factors

If complete model similarity is to be achieved, the model must in all respects be similar to the actual structure. It must first have geometrical similarity in that the model has dimensions to some scale factor K referred to the prototype in the x, y and z directions. This is called the length scale factor because it shows the relationship of all the corresponding measurements, i.e. $\frac{L_1}{L_s} = K$.

In static loading conditions, force and length enter into consideration. The connection is therefore made between these two dimensions for the static loading model analysis. The ratio of the load applied to a large model to that of a small one is called $X = \frac{W_1}{W_s}$, which is the load scale factor.

In the case of dynamic loading, the connection is made between the length and time scale factors. The time scale factor τ is the relationship between the periodic time of oscillation of the model and the actual structure.

The model theory for the case of static and dynamic bending may be illustrated for the example of a beam simply supported at the ends and centrally loaded, and for the case of torsion the beam may be fixed at one end and a torque applied at the other.

static bending (Fig. 1)

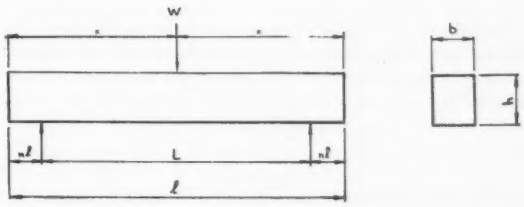


FIGURE 1.

For a beam with a length scale factor of K, the cross-sectional area and the second moment of area are related as follows:

$A_1 = b_1 h_1$ where '1' denotes actual structure

and $A_s = b_s h_s$ and 's' the model

and since $L_1 = KL_s$

$A_1 = Kb_s\, Kh_s$

$A_1 = K^2 A_s$ .....(1)

Similarly $I_1 = \frac{b_1 h_1^3}{12}$

and $I_s = \frac{b_s h_s^3}{12}$

therefore $I_1 = K^4 I_s$ .....(2)

For the relationship between static deflections the well-known elastic relationship to bending is:

$$\frac{d^2y}{dx^2} = -\frac{M}{EI} \qquad \text{.....(3)}$$

In equation (3), providing the model and actual structure are of the same material, both length and force dimensions must be scaled before the elastic relationship between the large and small models can be written.

Substituting for the length:

$$x_1 = Kx_s; \quad dx_1 = Kdx_s; \quad \frac{d^2y_1}{dx_1^2} = \frac{d^2y_s}{Kdx_s^2}$$

Similarly, if the load ratio be $X = \frac{W_1}{W_s}$

$$M_1 = L_1W_1 = KL_s.XW_s$$
$$M_1 = K.X.M_s \qquad \text{.....(4)}$$

Therefore $\frac{1}{K} \quad \frac{d^2y_s}{dx^2_s} = -\frac{M_1}{E_1I_1}$

and since $I_1 = K^4I_s$

$$-\frac{1}{K} \quad \frac{M_s}{E_sI_s} = -\frac{K.X.M_s}{E_1K^4I_s}$$

$$\frac{1}{KE_s} = \frac{X}{E_1K^3}$$

or $$\frac{K^2}{X} = \frac{E_s}{E_1} \qquad \text{.....(5)}$$

This gives the relationship of the modulus of elasticity with respect to the length and force ratios. If the material of the model differs from that of the actual structure and the length scale factor is fixed, so also is the load scale factor, determined by equation (5). (See also Ref. 2).

Similarly, it can be shown that if the model and the actual structure have the same material constants, i.e. $E_s = E_1$, and the length and load scale factors are applied:

$$y_1 = Ky_s \qquad \text{.....(6)}$$

and for the stiffness $k = \frac{W}{y}$ .....(7)

$$\frac{k_1}{k_s} = \frac{W_1}{y_1} / \frac{W_s}{y_s} = \frac{X}{K}$$

but $K^2 = X$

therefore, providing the modulus of elasticity and the load scale factors are related as in equation (5):

$$k_1 = Kk_s \qquad \text{.....(8)}$$

static torsion

If now a circular beam under torsion is considered, it can be seen how the modulus of rigidity of the actual structure is related to that of the model. From the theory of strength of material:

$$\frac{T}{\mathcal{J}} = \frac{C\theta}{L} \qquad \text{.....(9)}$$

θ the angle of twist $= \frac{TL}{\mathcal{J}C}$

The polar second moment of area $\mathcal{J}_1 = \mathcal{J}_s.K^4$; $T_1 = K\,X\,T_s$

Substituting for length ratios and eliminating θ:

$$C_1 = \frac{C_sX}{K^2} \qquad \text{.....(10)}$$

This is similar to equation (5).

Substituting from equation (5) for $\frac{X}{K^2}$ in equation (10):

$$\frac{C_s}{C_1} = \frac{E_s}{E_1}$$

which gives $\frac{E_s}{C_s} = \frac{E_1}{C_1} =$ Constant .....(11)

This means for model similarity the relationship of the Modulus of Elasticity to the Modulus of Rigidity must be constant when bending and torsional forces are applied. The torsional stiffness of an element is given by $k_t = \frac{T}{\theta}$ where θ is the angle of twist over a length L. This is analogous to the resistance to bending $\frac{W}{y}$.

If the torsional stiffness is $k_t = \frac{C\mathcal{J}}{L}$ the relationship between actual and model structures can be written as follows:

$$\frac{k_{t1}}{k_{ts}} = \frac{C_1.\mathcal{J}_s.K^4}{L_sK} \cdot \frac{L_s}{C_s\mathcal{J}_s} = \frac{C_1K^3}{C_s} \qquad \text{.....(12)}$$

but $$C_1 = C_s\frac{X}{K^2}$$

therefore $\frac{k_{t1}}{K_{ts}} = X.K.$ .....(13)

However, when both actual structure and model are of the same material:

$$E_1 = E_s \text{ and } C_1 = C_s; \quad X = K^2$$
then $k_{t1} = K^3k_{ts}$ .....(13a)

dynamic similarity

As previously stated, the connection for dynamic similarity is made between the length and the time scale factors.

For a vibrating beam of uniform cross-sectional area, supported on two supports, it can be shown that the differential equation for the motion is (Den Hartog[3]):

$$EI\frac{d^4y}{dx^4} = -\mu\frac{d^2y}{dt^2} \qquad \text{.....(14)}$$

The left side of the equation is the elastic expression for the loading while the right side is the maximum value of the inertia load, where μ is the mass of the beam per unit length;

$$\mu = \frac{A\gamma}{g}$$

Substituting the various material constants and scale factors in equation (14), it can be shown that:

$$\frac{K^2\gamma_1}{\tau^2E_1} = \frac{\gamma_s}{E_s} \qquad \text{.....(15)}$$

This equation gives the basic model set up for dynamic similarity. The relationship between the length scale factor and the time scale factor can easily be seen. It is governed by the materials used for the model and the actual structure and will be in the proportion to the modulus of elasticity and the specific weight of the material sused. Should the model and the actual structure be manufactured in the same material, i.e. if the modulus of elasticity and the specific weights are the same for both model and actual structure $E_1 = E_s$ and $\gamma_1 = \gamma_s$.

Then $K = \quad \tau$

The length ratio equals the time ratio.

torsional vibrations

When only masses and torsional forces apply the relationship for torsional vibrations is given by Timoshenko[4]

$$\frac{\mathcal{J}\gamma}{g}\frac{d^2\theta}{dt^2} - \frac{C\mathcal{J}d^2\theta}{dx^2} = O \qquad \text{.....(16)}$$

where $\frac{\mathcal{J}\gamma}{g}$ is the inertia load per unit length

and $C\mathcal{J}$ is the torsional stiffness of the shaft.

Again, by substitution of the material constants and scale factors in equation (16), it can be shown that:

$$\frac{K^2}{\tau} = \frac{\gamma_s}{C_s} = \frac{C_1}{\gamma^1} \qquad \text{.....(17)}$$

Equation (17) is similar to equation (15).

Substituting for $\frac{K^2}{\tau^2}$

$$\frac{\gamma_s}{\gamma_1} \cdot \frac{E_1}{E_s} = \frac{\gamma_s}{\gamma_1} \cdot \frac{C_1}{C_s} \qquad \text{.....(18)}$$

For dynamic similarity the ratios of the moduli of elasticity and of the moduli of rigidity of the actual structure and model must be equal. This is also the case for static similarity as shown by equation (11).

verification of model theory

To investigate model techniques and at the same time show how in actual practice model results can be relied upon, three types of model beams were investigated:

(a) box section
(b) Warren type beam
(c) Vierendeel type beam.

Two sizes of each beam were manufactured, the large beams having a depth and width of 4 in. and the small ones of 2 in., a length scale factor of 2 : 1 being employed in all cases. The models were of mild steel welded construction, allowance being made in the width and outer flanges for machining after welding and heat treatment.

As in effect all the beams are models they will not be referred to as actual structure and model, but the suffixes small and large (s and l) will be used to distinguish between the 2 in. and 4 in. size of beam.

Since in many machine tool structures, particularly lathe beds, planing and vertical boring machine cross-slides, the depth to length ratio between supports is often less than 8, it was decided that the models should also have a depth to length ratio lower than 8. This meant that the deflection due to shear on the cross-section had to be considered. This depth to length ratio of all the models was 5.67 : 1.

static bending

The beams were examined in two planes, namely "x-x" and "y-y". In the case of the box beam the second moment of area of the cross-section is constant and has equal values in both the x and y planes. For the other beams, the variation of second moment of area was calculated about the two axes and shown in a graphical form (Fig. 2).

For the box beams, the deflection due to bending with a concentrated load at the centre can be calculated from the standard formulae for a simply supported beam. The total deflection is equal to the deflection due to bending plus the deflection due to shear:

$$y = y_B + y_{Sh}$$

In the case of the Warren and Vierendeel beams, the cross-sections change throughout the length of the beams, but in the Warren type the change is more gradual than it is in the Vierendeel type beams. For both cases, when loaded in the x plane, the effect of the cross members can be neglected and an approximate result obtained by using the standard deflection formula for a simply supported beam, i.e.:

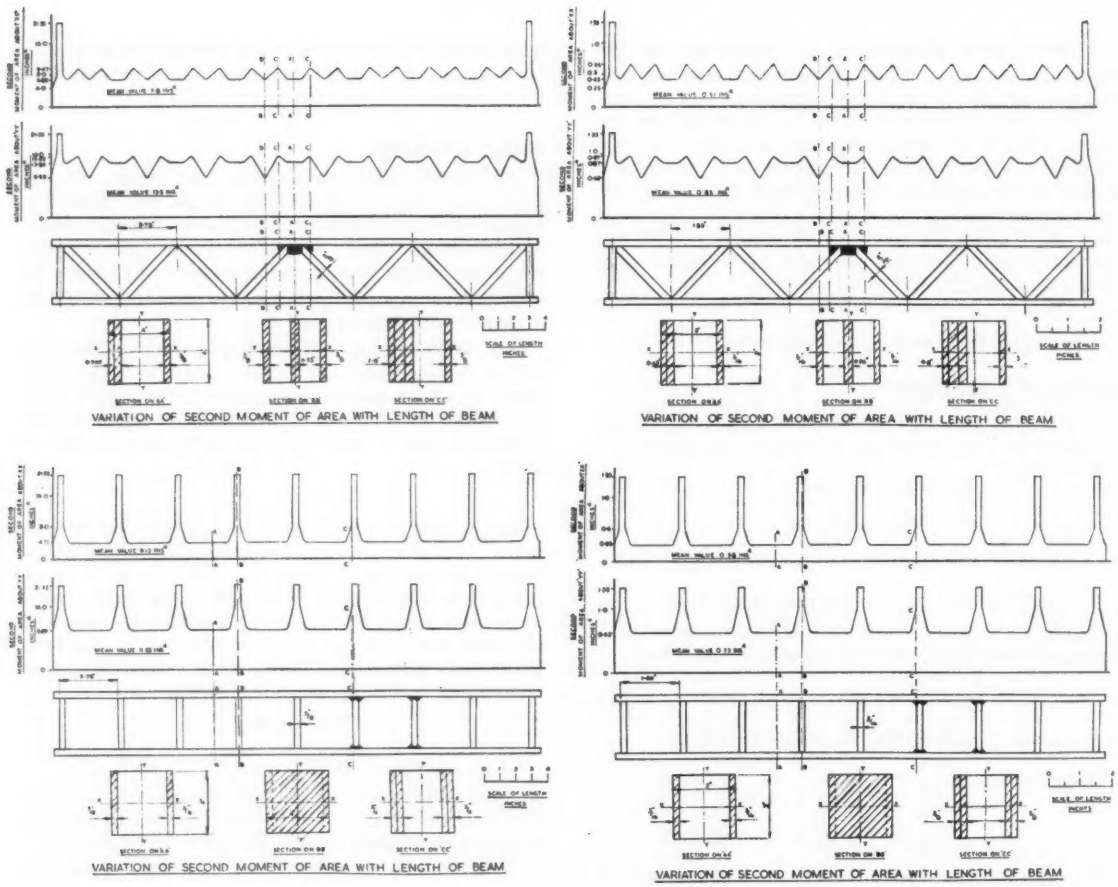
$$y = \frac{WL^3}{48EI} + \frac{\alpha Fx}{AC}$$

where I is the value for the two flanges only in the x direction, A is the area of the two flanges and α is a constant depending upon the type of cross section.

This method, however, gives the same result for both types of beam. It also gives a greater value than the one actually measured. This is to be excepted since the effect of the cross members has been neglected. Another approximate solution can be obtained for the deflection of the beam when loaded in the X plane if the mean value of the second moment of area about the "X-X" axis is used in the standard deflection equation. A graphical solution is better and more exact in that the change of section and the effect of rigid joints can be considered.

The deflection due to bending is $y = \iint \frac{M}{EI}\,dx$.

Since I also is varying in the above equation, it is necessary to consider this with the bending moment diagram. Integrating the $\frac{M}{I}$ curve twice by graphical means the deflection at any point along the length of the beam can be obtained. This method has been used to obtain the theoretical results of the central deflections due to bending in the x plane for the Warren and the Vierendeel beams. To obtain the theoretical deflections of the Warren and Vierendeel type beams when loaded in the Y plane the analysis of rigid frame structures was used. Since the beams were of welded construction, the joints had to be assumed rigid. The calculated and measured values of the stiffness are shown in tabulated form, Table I, Fig. 3.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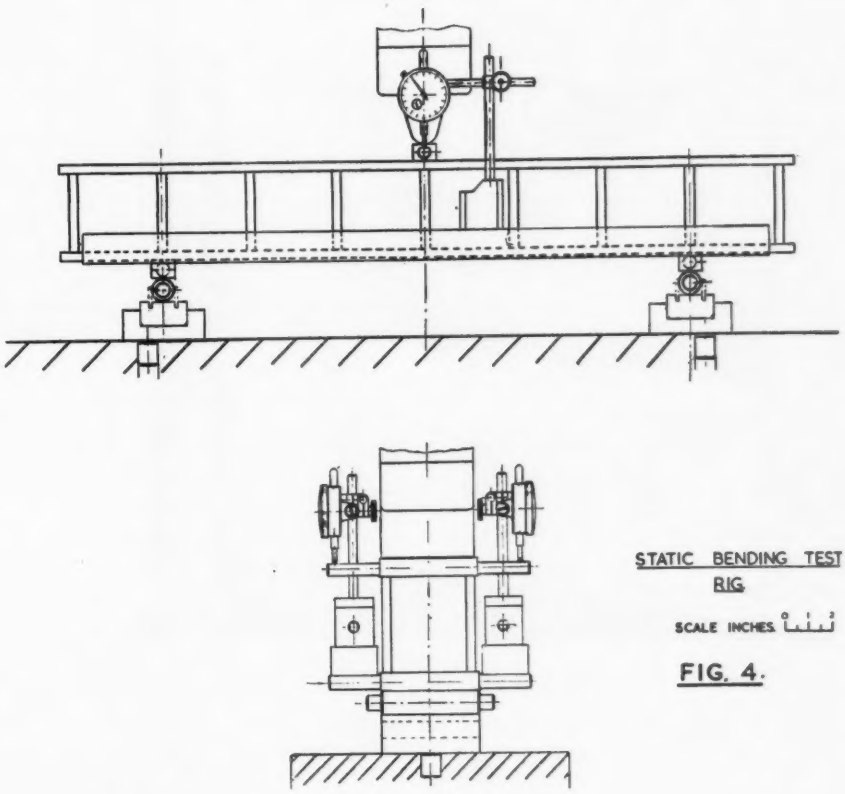
VARIATION OF SECOND MOMENT OF AREA WITH LENGTH OF BEAM
VARIATION OF SECOND MOMENT OF AREA WITH LENGTH OF BEAM

FIG. 2.

TABLE I

Beam	Axis	Weight lb.	% Diff. $W_1 = K^3 W_2$	Static Bending Stiffness			
				Measured 10^6lb./in.	Calculated 10^6lb./in.	% Diff.	% Diff. $k_1 = Kk_2$
Small Box		6·36	2·5	0·57	0·59	− 2·6	8·7
Large Box		52·18		1·25	1·18	6	
Small Box		6·36	2·5	0·55	0·59	− 6·8	14·7
Large Box		52·18		1·28	1·18	8·5	
Small Warren	I_{yy}	7·06	6	0·42	0·44	− 4·8	24
Large Warren		53·36		1·04	0·88	19	
Small Warren	I_{xx}	7·06	6	0·33	0·39	−14·7	15
Large Warren		53·36		0·76	0·77	− 1·8	
Small Vierendeel	I_{yy}	5·38	1	0·057	0·06	− 0·5	8
Large Vierendeel		42·70		0·123	0·12	0·25	
Small Vierendeel	I_{xx}	5·38	1	0·244	0·25	− 2·4	5·5
Large Vierendeel		42·70		0·515	0·501	2·8	

Fig. 3.



STATIC BENDING TEST RIG.

SCALE INCHES

FIG. 4.

measurement of deflection

The deflections of the beam were measured about both the x and y axis, when simply supported at both ends and a load applied at the mid-span position. A special fixture (Fig. 4) was manufactured so that deflection of the supports did not affect the measured deflections. Dial indicator gauges were positioned along each edge of the beam under test and the mean reading of similarly positioned clocks recorded (Fig. 5). The graphs showing the deflection/load characteristics for the two planes of loading for each beam are shown in Fig. 6 and the deflected shapes of the beams in Figs. 14(a) and 14(b).

static torsion characteristics

1. theoretical analysis

box section beam

For the section in the form of a hollow rectangle an approximate method for calculating the angle of twist for a given torque T over a length L, has been derived by J. Prescott[5]. If the outer boundary of the hollow rectangle has dimensions b and h and the sides have a thickness m,

$$\text{the torque } T = 2CL\theta \frac{m^2(b-m)^2(h-m)^2}{m(b+h) - 2m^2}$$

If then b equals h as is the case of the square box section beam

$$T = CL\theta\, m(b-m)^3$$

test rig

The main consideration in the design of the torsion test rig was that pure torsional forces only were to be transmitted to the beam under test, and that no bending forces were to be applied. This required that the torque be applied outside the supporting bearings of the beams.

A large lathe was chosen as the basic element of the test rig and the beams mounted between the headstock and the tailstock, Fig. 7. The tailstock barrel was removed and replaced by the torque shaft and bearings shown in Fig. 8.

The angle of twist was measured over the effective length of the beams. The length of arc through which each end of the beam rotated was measured with two sensitive dial clock gauges, graduated in 1/10,000 in., contacting with the measuring arms and positioned one at each end of the beam.

The dial gauges were supported and secured in position by large clock stands with magnetic bases, which were fixed to the bed of the lathe.

The measuring arms were positioned and secured one on each chuck of the test rig, so that the machined flats where the dial guages registered were on the centre line of the beam in the transverse horizontal axis. The distance between the measuring points was equal to the effective length of the beam. The different beam lengths were accommodated by positioning the lathe tailstock along the bed of the lathe. The measuring arms were used so that measurements could

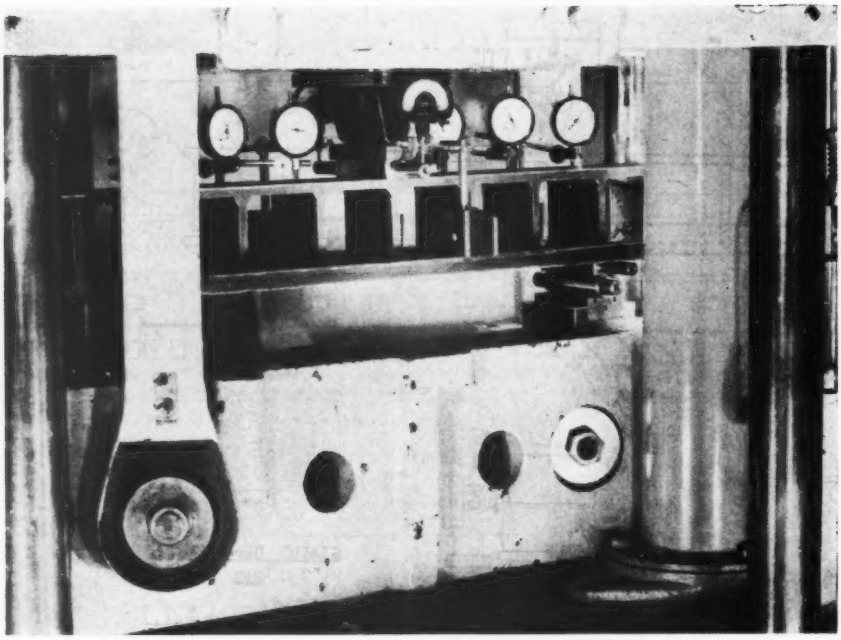


Fig. 5. Determination of the static bending characteristics.

be made over the centre lines of the beam and larger rotations recorded on the dial clock gauges. The vertical distance from the centre line of the beam to the point of measurement was 10 in. in all cases.

A small error was incurred in the measuring of the angle by this means, because the plunger of the clock gauge moved in a straight line, whereas the measuring arms moved along an arc. However, for small angles of twist experienced in the present work, the amount of error in the length of arc was less than 1% and was therefore neglected.

The beams were each in turn positioned in the chucks of the machine, and the tailstock locked to the bed of the lathe by its securing bolts. The tailstock was so positioned that the distance between the chuck faces was equal to the distance between the supports used in the bending stiffness tests, so that the effective length of the beam remained the same. By adjusting the screws in the headstock and tailstock chucks, it was possible to locate and grip the beams so that the axis of the beam lay on the axis of the machine spindle (i.e. the beam was on centre).

The headstock chuck of the machine was prevented from turning in the direction of the applied torque by a stop block which was positioned on the bed of the lathe and the spindle face plate.

Weights were applied simultaneously to each of the loading stirrups causing the torque lever to rotate and apply the torque to the beam. An initial load was applied to each stirrup to remove any backlash and to locate the stopping device between the spindle face plate and the bed of the lathe.

Only slight movement of the headstock chuck, corresponding to about 5% of the tailstock chuck, was noted in all cases.

To obtain the angle of twist over the effective length of the beam, the headstock gauge readings were subtracted from the tailstock gauge readings for every increment of torque.

From these results the graphs in Fig. 9 were drawn, from which both the model similarity and the corresponding torsional stiffness of the different beam structures could be compared.

dynamic bending characteristics

fundamental frequency

The beams were made longer than the distance chosen as the supporting length in the static and dynamic investigations in order to enable the additional length to be used for clamping purposes in the torsion tests. In the static bending analysis the additional length overhanging each support was neglected. The only force acting on that length, i.e. that due to its own weight, was small in comparison with the external force applied midway between the supports. In the dynamic investigation this additional length had to be considered since the mass of the beam provided the inertia forces which produced the deflected shape at resonance. The fundamental frequency for an overhanging beam can be determined by means of Rayleigh's method[3].

dynamic test rig

This rig had to provide support for the models so that the supporting conditions were as near as possible identical to the static bending conditions. The general view of the test rig is shown in Fig. 10. It consists mainly of (1) the bed plate (2) supports for each end of the beam and (3) a central support on which the vibrator could be mounted seismicly.

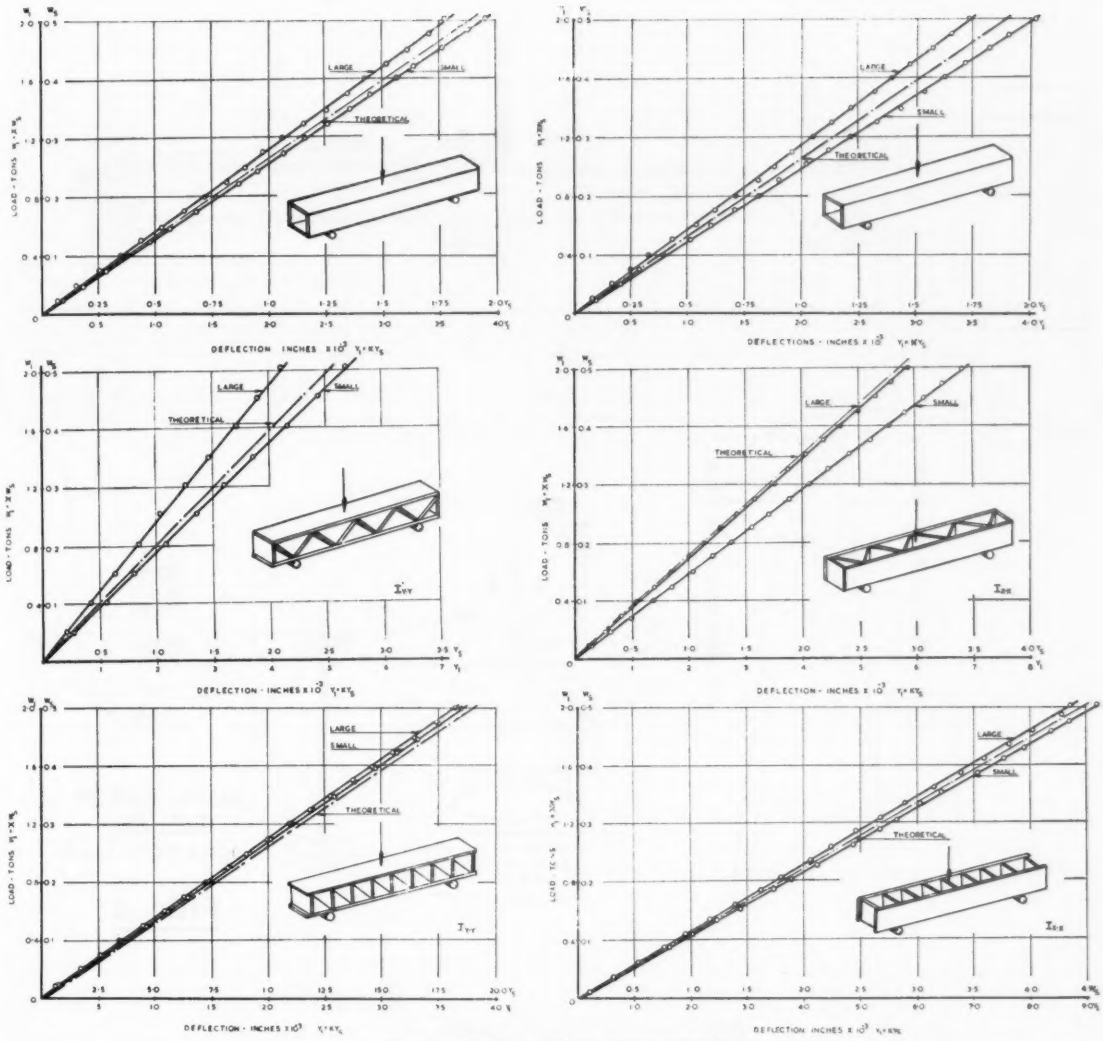


Fig. 6. Static bending characteristics.

Due to the reversal of force under dynamic conditions, the beam had to be restrained from lifting off its supports, and therefore had to undergo some constraint at its ends different from the static loading conditions. This, however, was minimised to some degree by using flexible springs as supports and placing hardened steel balls between the springs and the beam (Fig. 11).

An electrical vibration generator, driven by a power oscillator, was used to excite the beams. The frequency range available was adjustable from 10 c.p.s. to 10,000 c.p.s. and the force output of the vibrator was maintained at 5 lb.

The vibration measuring circuit (Fig. 12) consisted of the following units:

(1) piezoelectric transducer
(2) cathode follower
(3) amplifier and integrating unit
(4) wave analyser
(5) oscilloscope (double beam).

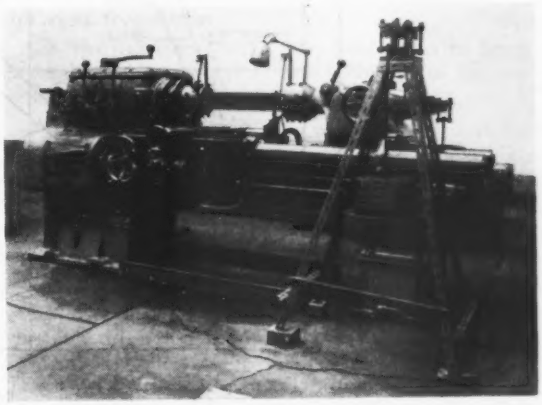


Fig. 7. Determination of the static torsion characteristics.

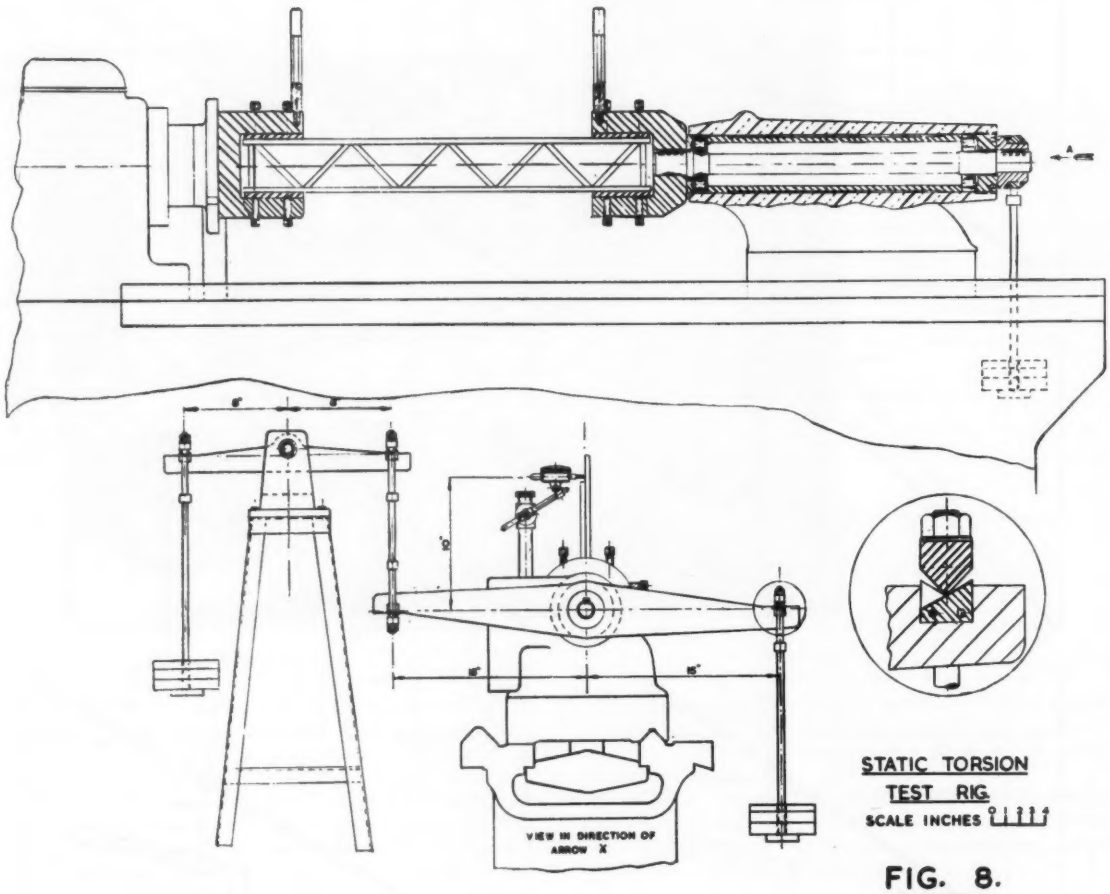


FIG. 8.

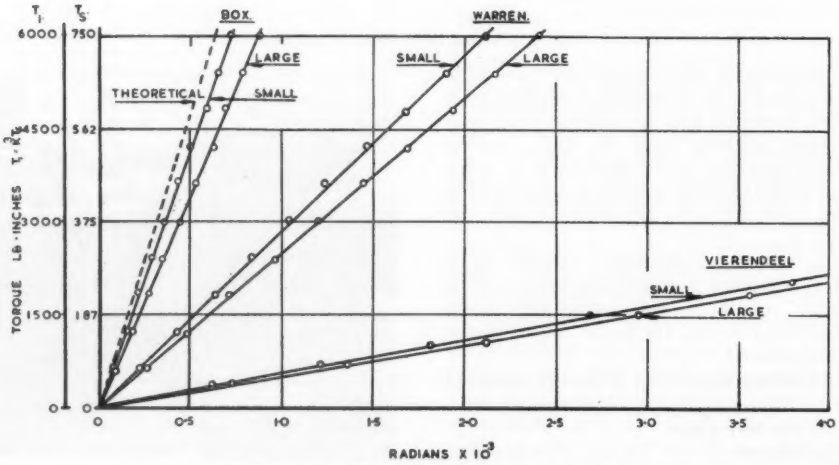


Fig. 9. Static torsion characteristics.

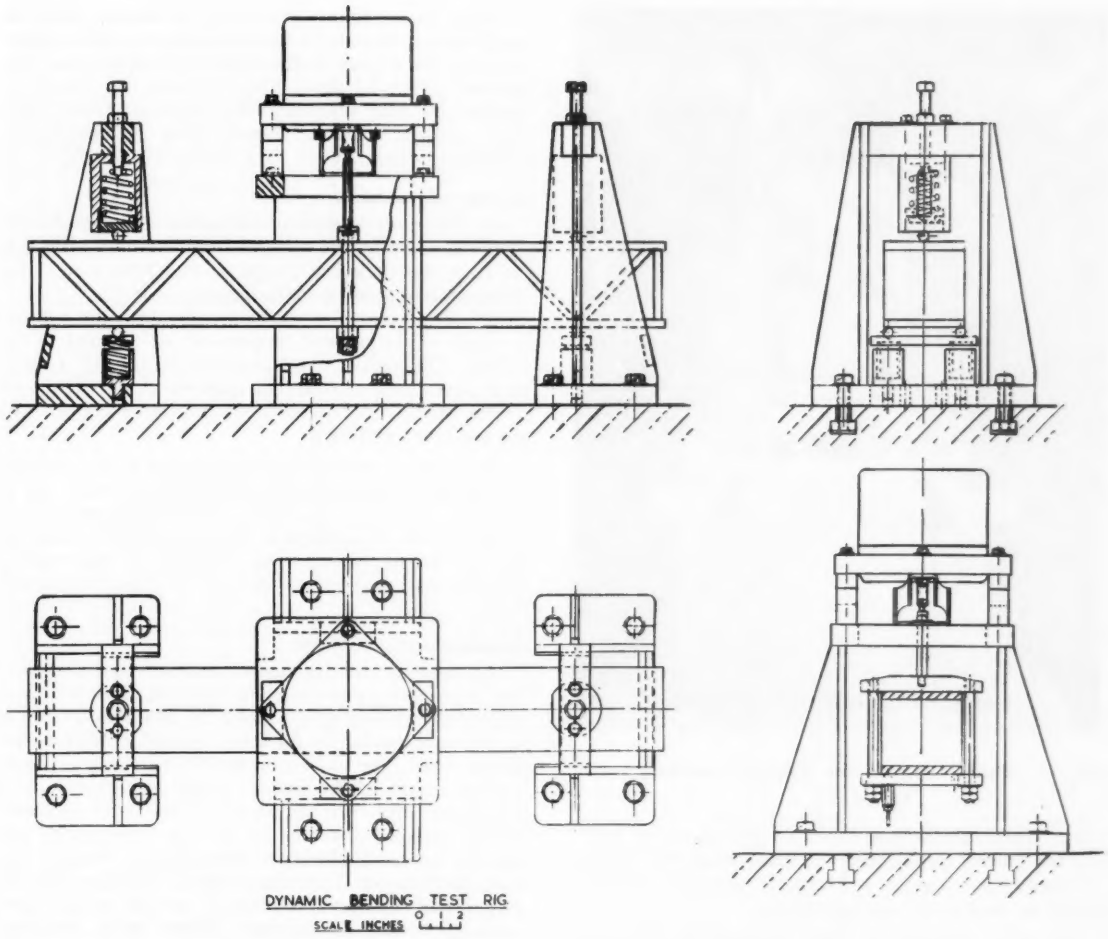


FIG. 10.

mounting and excitation of the beams

For the dynamic bending tests the beams were again examined in both the "X-X" and "Y-Y" planes as in the static bending tests.

The beams were in turn mounted in the test rig and the dynamic force applied vertically in the same plane as the supports. Again, as in the static bending tests, the mid-span position was chosen as the point of load application. To obtain the amplitude-frequency curves the "pick-up" was mounted at the mid-span position in the direction of the exciting force and transversely situated 0.18 in. and 0.09 in. from one edge of the large and small beams respectively. Readings were taken with the pick-up positioned first at one side and then at the other side of the beam.

In order to examine the vibration shape of the beams at various natural frequencies, small light-weight 'G' clamp brackets were manufactured to clamp and position the pick-up at various points along the beam other than the central position where the driving clamp bracket was situated.

measuring procedure

resonant frequencies

(i) The transducer was rigidly attached to the beam at the central position in the direction of the exciting force.

(ii) The driving oscillator was used to feed the current at the required excitation frequency to the vibrator. By adjusting the current output from the oscillator to 1.0 amp. r.m.s., the force output of the vibrator was maintained at 5 lb.

(iii) The output signal from the accelerometer was fed via the cathode follower to the oscilloscope.

(iv) In each test on the large beams the oscillator was run through the frequency range 100 c.p.s. to 2,500 c.p.s. and for the small beams 150 c.p.s. to 3,500 c.p.s., while the acceleration amplitude was observed on the oscilloscope screen. This gave a quick indication of the positions of the natural frequencies of the beams.

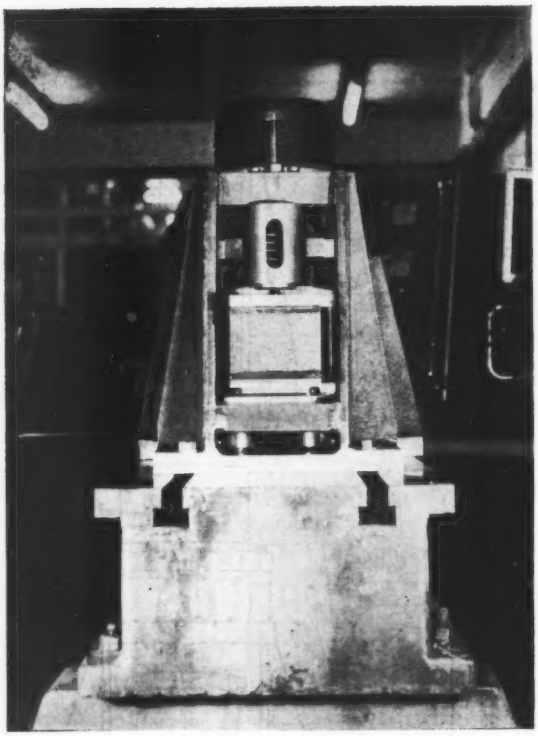


Fig. 11. Beam supports for dynamic bending tests.

(v) The test was then repeated but instead of feeding the output signal from the integrating unit to the oscilloscope, it was fed through the amplifier and integrating unit to the wave analyser.

For every reading, the wave analyser was tuned to the same frequency as that of the driving oscillator, so that only signals of the same frequency as that of the exciting force were recorded.

With the previous knowledge obtained from the oscillograph screen it was possible to take greater care in the region of the resonant frequencies. This proved to be of great help because the resonance peaks were very sharp and the frequency bandwidths very narrow, as will be seen from the amplitude-frequency curves, Figs. 13(a) and 13(b).

modes of vibration

(i) From the amplitude-frequency curves it was possible to select the natural frequencies of vibration so that the deflected shape of the beams at those frequencies could be investigated.

(ii) The frequency was excited in the same manner at each of the natural frequencies as selected in (i).

(iii) The pick-up was attached to the 'G' clamps and positioned at different stations along each edge of the beam, the displacement amplitude being noted on the wave analyser.

Only slight differences of readings were recorded for similar positions along both edges. This was to be expected since the beams were symmetrical and subjected to symmetrical loadings. The deflected shapes of the beams when excited at the various natural frequencies are drawn in Figs. 14(a) and 14(b).

measurement of phase

To assist in the drawing of the deflected shapes of the beam, it was necessary to note the phase relationship of the various points along the beams with that of a reference point. To do this a second accelerometer of the same type as mentioned before was positioned at the centre of the beam, which was chosen as a reference point. The output of this reference accelerometer was fed directly on to one channel of the double beam oscilloscope after passing through the cathode follower. The output signal from the cathode follower of the movable pick-up was fed to the other channel of the oscilloscope. When both accelerometers were positioned on centre, the two signals were in phase with each other and one trace lay immediately above the other. As the movable pick-up

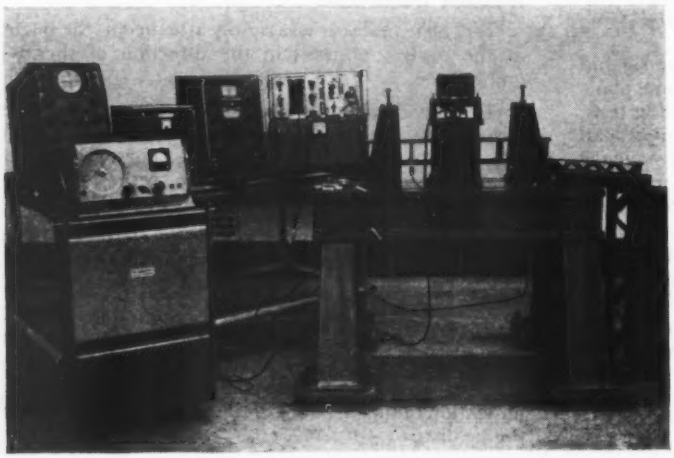


Fig. 12. Determination of the dynamic bending characteristics.

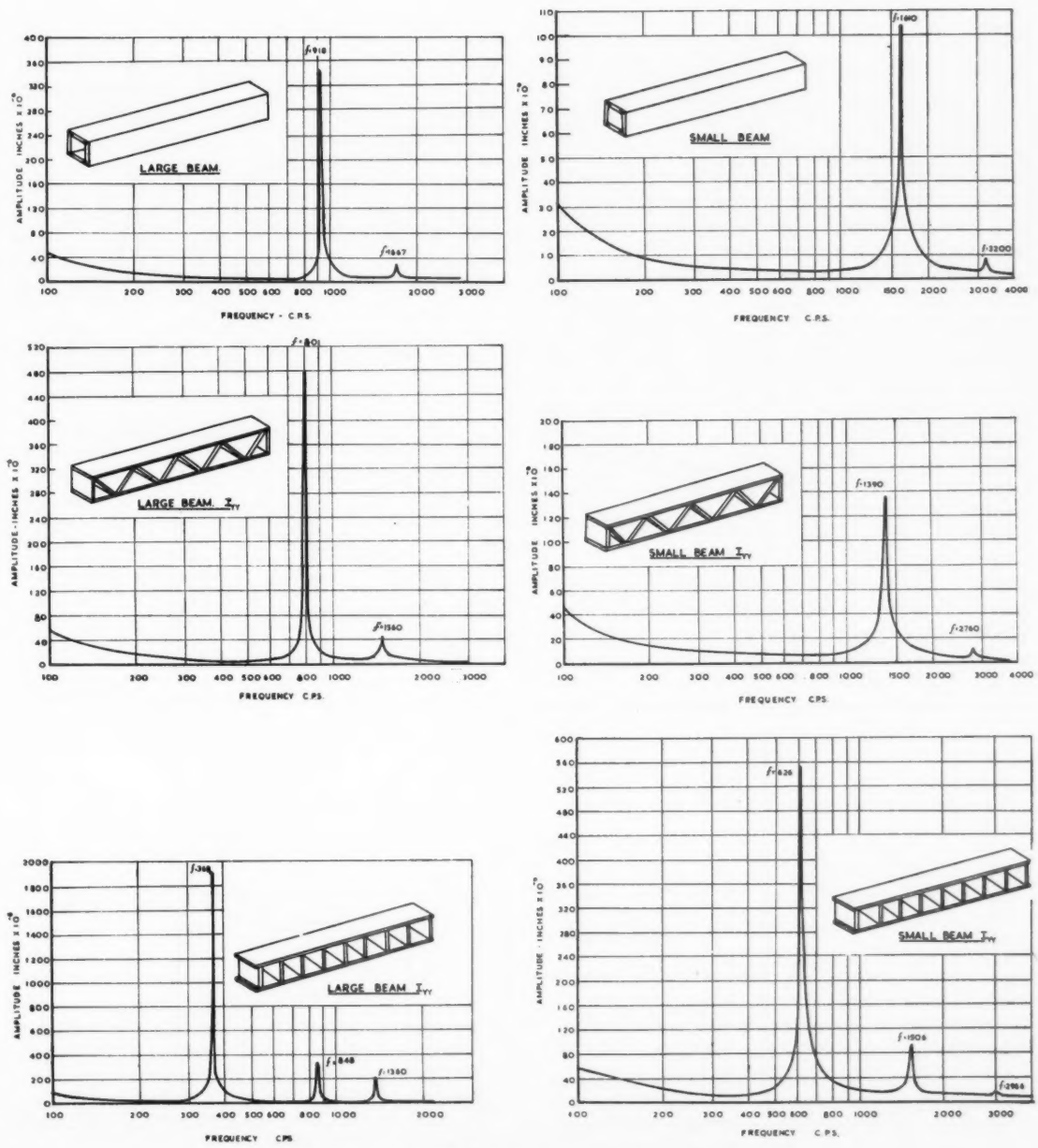


Fig. 13(a). Dynamic bending response curves (I_{yy})

was positioned at the different stations, particularly in the case of the higher mode of vibration, the change of phase could clearly be seen on the oscilloscope screen.

torsional natural frequencies

In the determination of the torsional natural frequencies, the same lathe and headstock chucks used in the static torsion tests were again used to support and hold the beam. The tailstock chuck and torque lever were removed and replaced by the lathe tailstock barrel, fitted with a rigid centre (Fig. 15) which supported the beams at the tailstock end of the lathe. To accommodate the beams in this manner, countersunk centre holes were machined on the centre axis in the end cross spars of the Vierendeel and Warren type beams. In the case of the box section beams, blocks were machined to fit into the end of the beam, so that a centre hole could be bored on the centre axis of the beam.

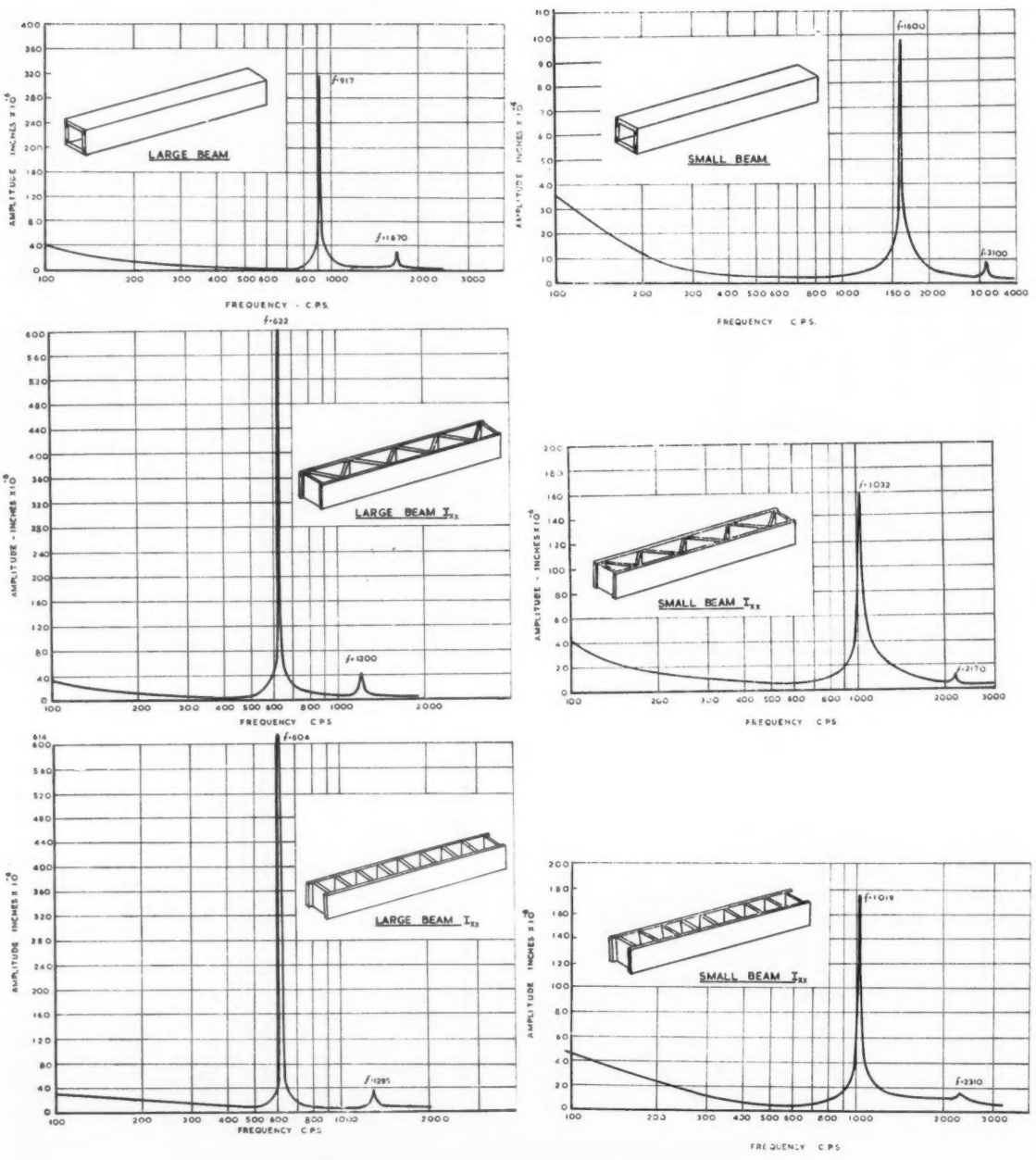


Fig. 13(b). Dynamic bending response curves (I_{xx}).

In order to provide the twisting moment for the excitation of the beam, clamps brackets and torque arms were manufactured, so that a force at right angles to the torque arms produced a twisting moment on the beam. The exciting force was produced by striking the torque arm. The torque arms were positioned on the centre line of the beam and in line with the tailstock centre so that a minimum bending force would be transmitted to the beam. The same piezoelectric accelerometer and cathode follower used in the dynamic bending tests were again employed to supply the signal for measuring the torsional frequencies. Small, lightweight 'G' clamps were manufactured to secure and position the pickup on the beams. The 'G' clamps were so designed that the accelerometer acted at 90° to the *x-x* and

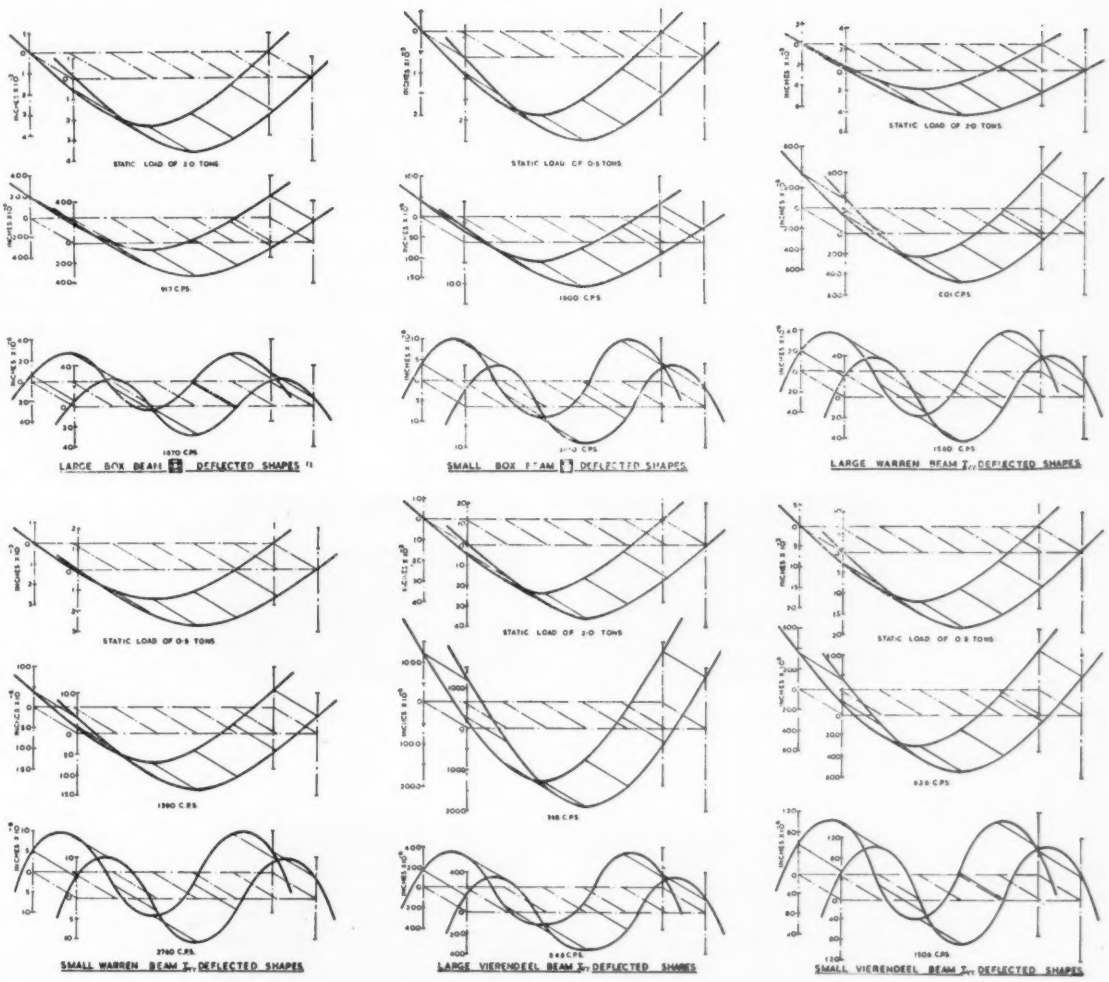


Fig. 14(a). Deflected shapes (I_{yy}).

y-y axis. The locating face of the accelerometer was positioned on the centre line of the beam section.

The accelerometer and 'G' clamp were positioned at the tailstock end of the beam where the maximum amplitude of movement was to be expected. The output signal from the accelerometer was fed via the cathode follower to one channel of the double beam oscilloscope. With the time base of the oscilloscope switched off a calibration signal of 50 c.p.s. was fed to the other channel of the oscilloscope and used as a time marking device. With the lens aperture of the camera open and the film moving through the camera, a slight tap was given to the torque arm. The resulting rotary oscillations of the beam produced a signal in the accelerometer which was displayed on the oscillograph screen along with the calibration signal, and recorded on the moving film in the form of a trace.

The oscillograms are shown in Fig. 16 from which the torsional natural frequencies have been estimated.

discussion of results

When models are employed as an aid to design, tests would first be carried out on the models and from the results, the behaviour of the prototype predicted. In the following discussion of the results, all comparisons between actual structure and model are, therefore, given with respect to the model, which is considered to be equivalent to the small beam. The results of the larger beam tests are always quantitatively compared ($\pm x\%$), with respect to the smaller ones.

static bending

The parameter examined in the static bending tests was the deflection of the beam when supported

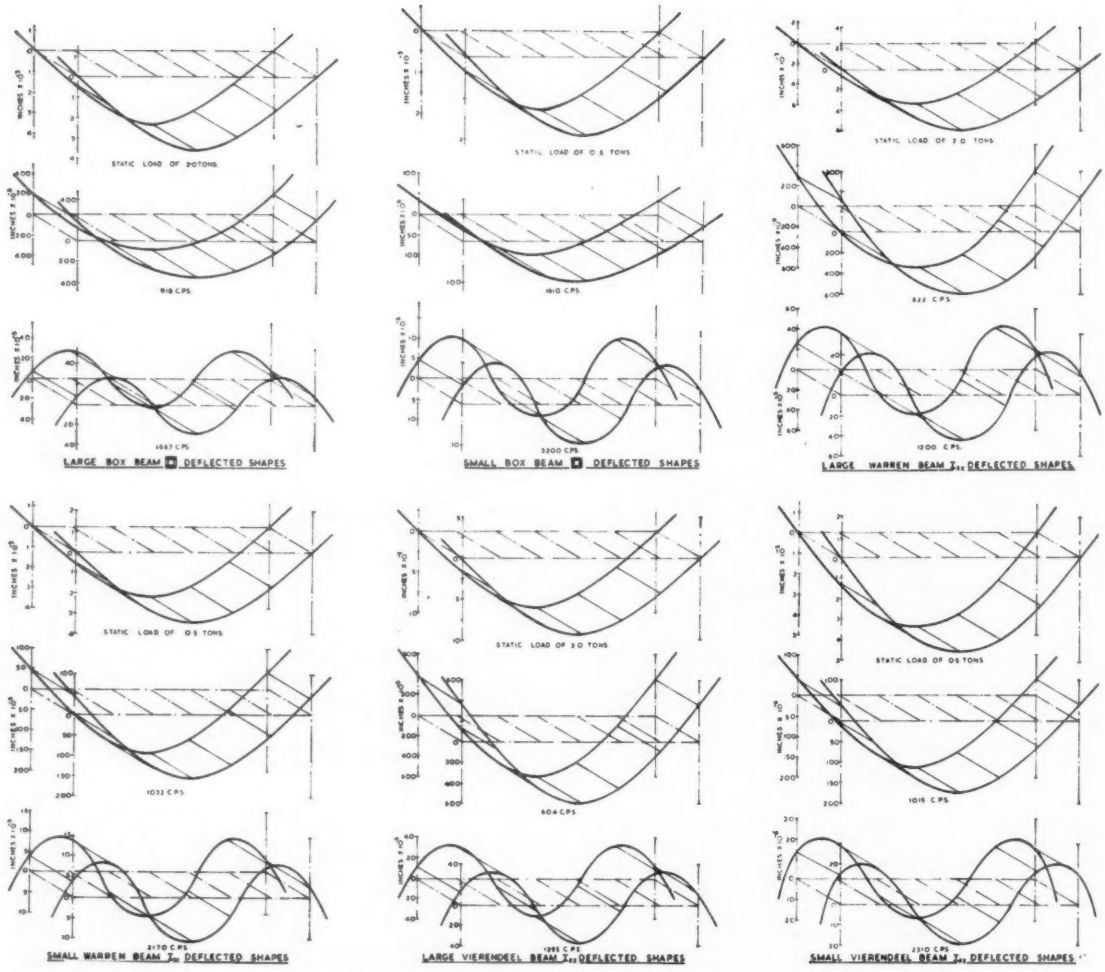


Fig. 14(b). Deflected shapes (I_{xx}).

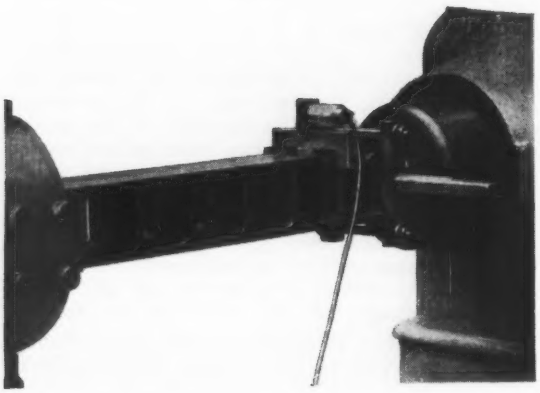
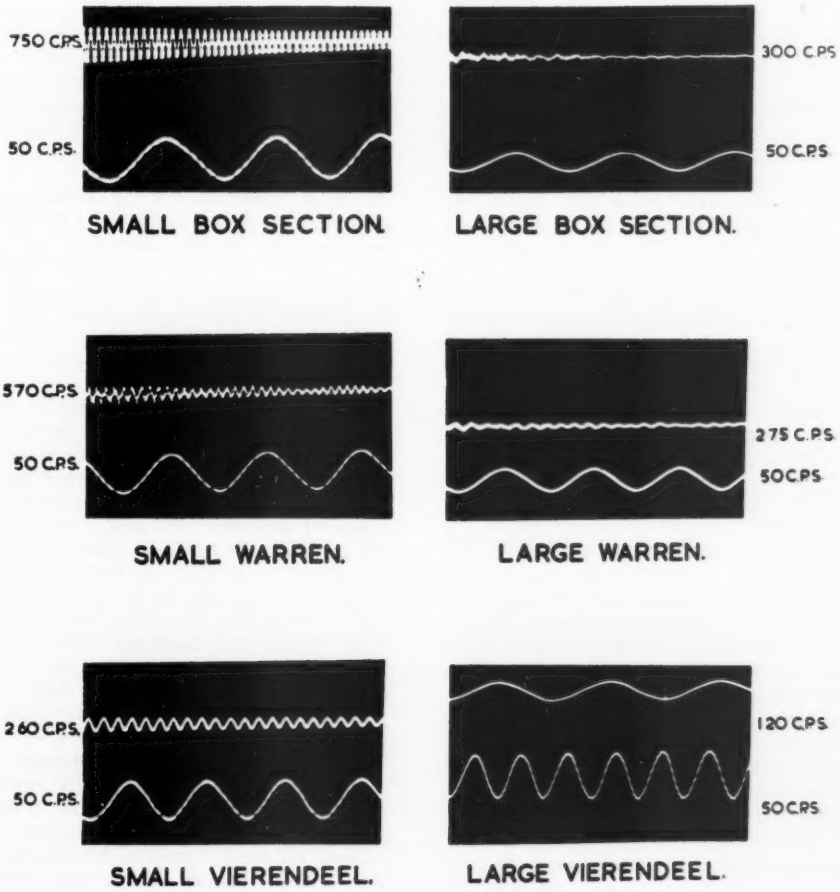


Fig. 15. Determination of the torsional natural frequencies.

on two supports and loaded centrally. The beams were examined in two axes, x-x and y-y, the deflection being measured at several points equally spaced from the centre along the length of the beam.

In Table I, Fig. 3, the weights and stiffness figures measured in two axes for the various beams are shown. Comparison of the weights for any particular pair of beams compares with the model ratio of K^3, the maximum percentage difference being of the order of 6%.

The load-deflection characteristics for loading in both planes of bending are given in Fig. 6. These graphs include both the theoretically calculated and the measured values of deflection. The load deflection characteristics of both the large and small beams of any one type, loaded about the same axis are drawn on the same graph, with the scale of the axes adjusted according to the model laws. In all cases, the deflection ratios are comparable with the model laws $y_1 = Ky$. The greatest difference between the large and small beams in both directions of bending was found in the case of the Warren type beams. The maximum percentage difference (20%) from the model law of $y_1 = Ky$ was found for the Warren type beams loaded in the direction of the y axis. Manufacture of these beams proved more difficult than that of the other types of beams, because of the angle of the cross-spars. Difficulty was experienced, particularly on the small Warren beam, in obtaining uniform welds throughout the structure, and uniformity throughout the length of any particular weld. This was due to the difficult angle of electrode approach, which was governed by the length of weld and the space between the two outer spars of the beam.



TORSIONAL NATURAL FREQUENCIES.

FIG. 16.

TABLE II

Beam	Torsional Stiffness	
	10^4lb. in./Rad.	$\frac{k_{t1}}{k_{t2}} = K^3$
Small Box	1·03	$K^{2\cdot7}$
Large Box	6·9	
Small Warren	0·357	$K^{2\cdot81}$
Large Warren	2·5	
Small Vierendeel	0·069	$K^{2\cdot9}$
Large Vierendeel	0·51	

Fig. 17.

For the type of beam design used in the present investigation, calculations of the theoretical deflections served as a check on the experimental procedure. Although the average values were much smaller, the maximum difference between the results, theoretically calculated by the different methods outlined in the text, and the measured deflections of the beams, was of the order of $\pm 14\%$. Even this might be sufficiently accurate from the point of view of the designer. In all cases the larger beam appeared to have the higher stiffness value. This could again be attributed to the welded joints. The welds produced on the larger beams were smoother and more uniform in section than the welds on the smaller beams. Inspection of the welds revealed that the smaller welds had quite a large throat radius, whereas the welds in the large beams were straight, such that the throat length and leg length of the welds were equal.

However, whilst the larger beams appeared to have the higher stiffness, in some work published by Opitz[1] and Bielefeld[6], the smaller models were found to be stiffest.

From the static load characteristics, a comparison can be made between the three types of beam design. The box section offers higher stiffness than the other types of beams. Care must be taken, however, when large panels subjected to high shear stress are employed, as warping and buckling of the panels may take place. Where large panels with thin walls are required for low weight with resulting high natural frequency, some means must be found for stiffening the panels. One example is the use of cellular box construction[7 & 8].

The stiffnesses of the Warren and Vierendeel beams in the *x-x* axis were of similar order, although the Vierendeel beam obtained its strength mainly from the outer spars, the cross-spars providing little or no resistance to the bending force. When these two beams were loaded in the *y-y* axis, the stiffness of the Warren beams was seven and a half times greater than that of the Vierendeel.

static torsion

The variation of angle of twist with applied torque is plotted in graphical form (Fig. 9) for all the beams. With the torque applied to the large and small beams according to the model law $T_1 = K^3 T_s$, the angles of twist over the effective length of the beams should be equal and the angle of twist per unit length would be $\theta_1 = \frac{\theta_s}{2}$. For each pair of beams for any particular design, experimental results appeared to confirm this, at least approximately. The percentage difference in the Vierendeel beams was of the order of 7% and in the Warren beams 12%, the maximum difference of 16% occurring in the case of the box section beams.

The percentage difference between the angles of twist of the large and small beams appeared to be greater with beams of a higher torsional stiffness. This was probably due to small errors occurring in the readings, in the torque applied or in the setting of the beams in the test rig.

In the case of the box section beam where a theoretical calculation of the angle of twist was possible, the measured and calculated values could be compared. For the small beam, the difference was of the order of −8%, but for the larger beam it was very high, −35%.

The torsional stiffness values of the beams are shown in Table II, Fig. 17. From these figures the stiffness scale factor equal to K^3 by model laws could be compared. For the Vierendeel and Warren beams the values were $K^{2\cdot9}$ and $K^{2\cdot8}$ respectively. The greatest divergence from the model theory occurs in the case of the box section beams where the value of $K^{2\cdot7}$ gave a difference of 10%. In this manner, the model similarity was again proved in the static torsion tests.

A particular point of interest in the torsion characteristics is that the smaller beams have the higher torsional stiffnesses, whereas in the bending tests, this was reversed, the larger beams being the stiffest. Whilst this may be coincidental, it could be observed that this was possibly due to buckling of the panels under torsional shear stresses. Timoshenko and Bleich show that the flexural rigidity of a plate grows with the cube of the plate thickness, and that the buckling load decreases with the square of the plate width and increases with the cube of the thickness. Any irregularities, therefore, in the width and wall thickness of the larger beams would have a greater effect upon the torsional stiffness than in the case of the small beams.

Comparison between the torsional characteristics of the different designs could be made in the same manner as in the case of static bending. For the particular designs investigated, the stiffness values showed the same trends as in the bending tests, the box section beams having the highest and the Vierendeel the lowest torsional stiffness.

dynamic bending

In the model analysis it was shown (Equation 15) that for actual structure and model of the same material having equal values of Young's Modulus E

TABLE III

Beam	Axis	First Resonant Frequency				Second Resonant Frequency		
		Calculated f.c.p.s.	Measured f.c.p.s.	$\frac{f_s}{f_1}=K$	% Diff. of K	Measured f.c.p.s.	$\frac{f_s}{f_1}=K$	% Diff. of K
Small Box		1750	1610	1·75	12·5	3200	1·92	4
Large Box		868	918			1667		
Small Box		1750	1600	1·75	12·5	3100	1·85	7·5
Large Box		868	917			1670		
Small Warren	I_{yy}		1390	1·74	13	2760	1·77	11·5
Large Warren			801			1560		
Small Warren	I_{xx}	1280	622	1·66	17	2170	1·8	10
Large Warren		660	1032			1200		
Small Vierendeel	I_{yy}		626	1·7	15	506	1·79	10·5
Large Vierendeel			368			848		
Small Vierendeel	I_{xx}	1160	1019	1·69	15	1295	1·78	11
Large Vierendeel		585	604			2310		

Fig. 18.

and $\gamma_1=\gamma_s$ that the length ratio equals the time ratio, i.e. $K=\tau$

The amplitude-frequency curves were drawn, Figs. 13(a) and 13(b) and the resonant frequency values shown in Table III, Fig. 18, where the theoretical values are also compared. The ratio f_s/f_1 varies between 1·66 and 1·75, the greatest difference from the theoretical value of 2 occurring in the case of the Warren beam when excited in the *x-x* axis. The low value of 1·66 giving a difference of 17%, could be expected in view of the results obtained in the static bending tests.

The resonant frequency curves showed that very little damping existed in the structures. The rise in amplitude was very high at the resonant frequency and the frequency bandwidth very narrow.

The higher resonant frequencies shown in the curves compared well with the model similarity theory. Again, the results are tabulated in Table III.

Where a mean second moment of area could be derived, either by calculation or graphical methods, the theoretical values for the first resonant frequency were determined. These values were in all cases comparable with the measured values, the results again following the same pattern as in the static bending results.

Not only the resonant frequency values, but also the deflected shapes during resonance, should be in accordance with the model similarity theory. For this reason, the deflected shapes of the beams at the various resonant frequencies were drawn in Figs. 14(a) and (14b). For the case of the small beams, they bore always good resemblance to the corresponding larger beams at the particular frequencies and direction of excitation.

It will be noticed on all the amplitude-frequency curves, that the amplitude rises towards the lower frequency end of the curves. This is due to the spring supports resonating at 80 c.p.s., causing relatively higher displacements of the beams.

torsional natural frequencies

The torsional natural frequencies were estimated from the oscillograph records of Fig. 16. For the small box section beam, the measured value of 750 c.p.s. compared well with the calculated value of 828 c.p.s. (a difference of −10%) and for the large box section beam 300 c.p.s. was estimated, compared with the calculated value of 410 c.p.s., a percentage difference of −25%. In view of these and the static torsion results, the experimental procedure was considered satisfactory. The ratio of 750/300=2·5 compared with the model ratio of 2·0 was therefore considered reasonable under the circumstances, because such a difference had to be expected in view of the static torsion results.

For the Warren beams the measured value of 570 c.p.s. for the resonant frequency of the small beam and 275 c.p.s. for the large beams gave a ratio of 2·08 compared with the model ratio of 2·0.

In the case of the Vierendeel beams, the torsional resonant frequency of the small beam was 260 c.p.s. and that of the large beam 120 c.p.s. Again, the ratio $\frac{f_{ts}}{f_{t1}}=2{\cdot}18$ agreed well with the model ratio of 2·0.

None of the torsional natural frequencies given above appeared to be shown up during the dynamic bending tests. This was possibly due to the fact that the point of excitation and the positioning of the

pickup for the determination of the amplitude frequency curves coincided with the nodal point of the first torsional natural frequency.

practical application to design work

machine bed

An investigation into the stiffness properties of a more complex structure of similar proportions to an actual machine tool, was carried out on a bed for a special machine tool rig. A half-scale model of the machine was manufactured and tested. A drawing of the machine bed is shown in Fig. 19.

The full size machine bed and the model were of mild steel fabrication, heat treated after welding and the guide faces machined as shown on the drawing. The full size and model were secured and grouted to the concrete floor so that as far as possible normal working conditions were maintained.

static bending tests

The resistance to bending in the transverse direction of the two outer support rails was measured on both machine beds. A static force was applied through a calibrated loading rig, between the two outer support rails, Fig. 20, midway along the length of the rails. The deflection of the support rails was measured at the centre span position, using dial indicators supported independently of the machine bed. A combined graph of the load-deflection characteristics of the full size and model bed are shown in Fig. 21.

dynamic bending tests

(a) horizontal transverse tests

The vibration generator was so positioned (Fig. 22) that an exciting force could be applied midway along the length of one of the support rails, and at 90° to the length of the rail in the transverse horizontal direction. The vibrator was mounted in a horizontal position on a bed plate which was secured to the floor, and the coupling made between the vibrator spindle and the mild steel top rail of the slide support.

Movement in the direction of the exciting force was measured with an accelerometer secured to the machine bed and positioned alongside the connecting rod.

The full size machine bed was excited over a frequency range of 30 c.p.s. to 1,000 c.p.s. and the model bed from 60 c.p.s. to 2,000 c.p.s. The combined amplitude-frequency curves are shown in Fig. 21.

(b) horizontal longitudinal tests

The vibration generator was mounted in a horizontal position at one end of the slideway support,

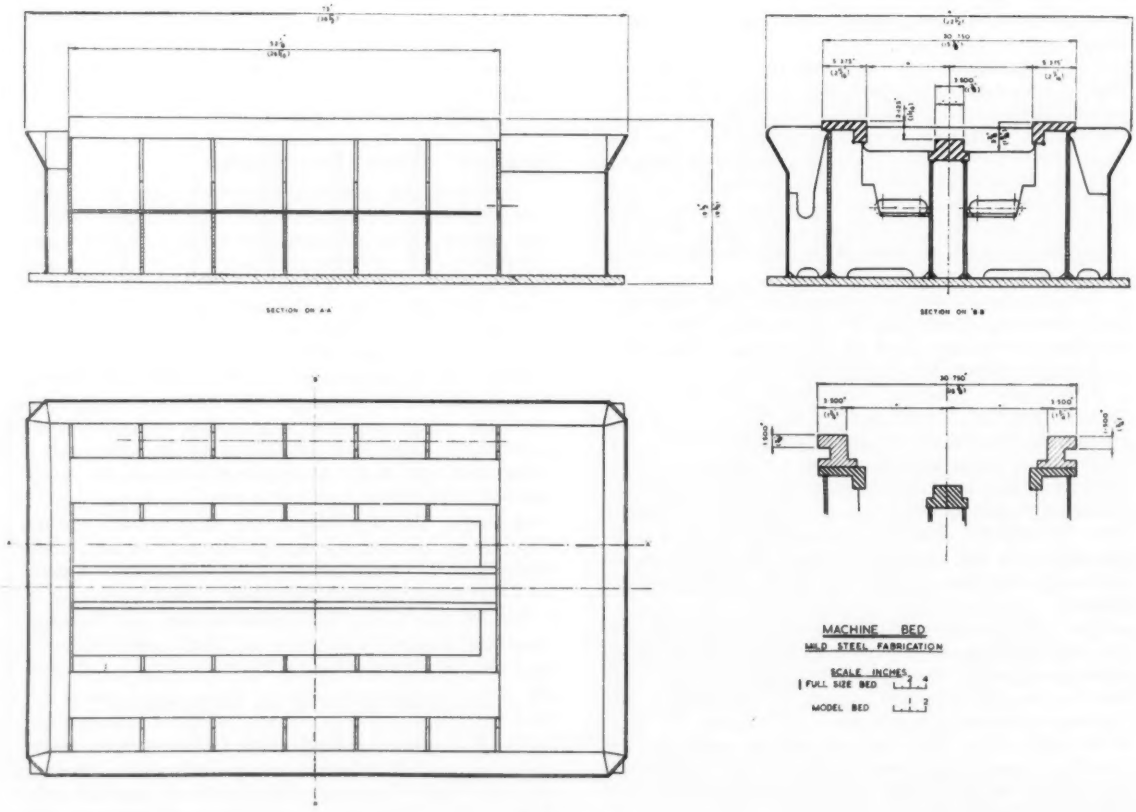


Fig. 19.

Fig. 23, in such a way that the exciting force acted along the length of the bed. Again the coupling was made between the vibration generator and the mild steel top rail of the slide support, and the accelerometer positioned to one side of the connecting rod.

The frequency range of excitation for both machine beds were the same as in the transverse tests. Curves showing the amplitude-frequency characteristics in the longitudinal direction are drawn in Fig. 21.

A larger type of vibration generator was available for the investigation on this full size machine bed. Since a force of 10 lb. could be obtained with this type of vibrator, it was decided to use it in preference to the small vibrator, which was used for the previous models and the model bed. The large vibrator had its own trunnion mounting which enabled it to be mounted on the base plate of the full size bed for the longitudinal tests. This eliminated the use of a very long connecting link between the vibrator spindle and the machine bed.

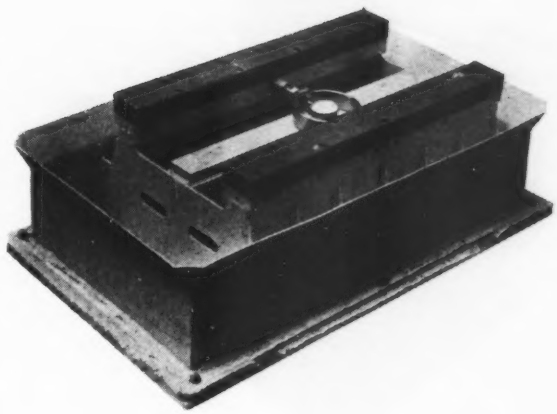
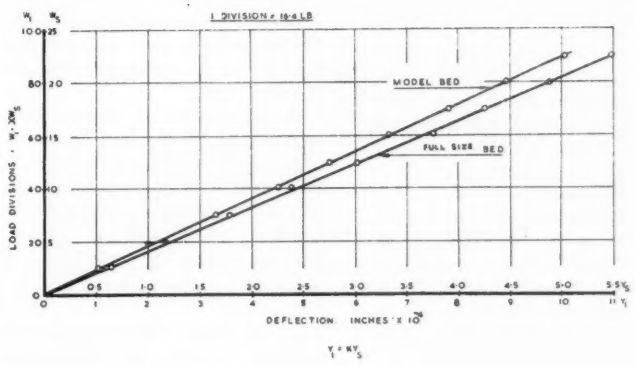


Fig. 20. Static loading of model machine bed



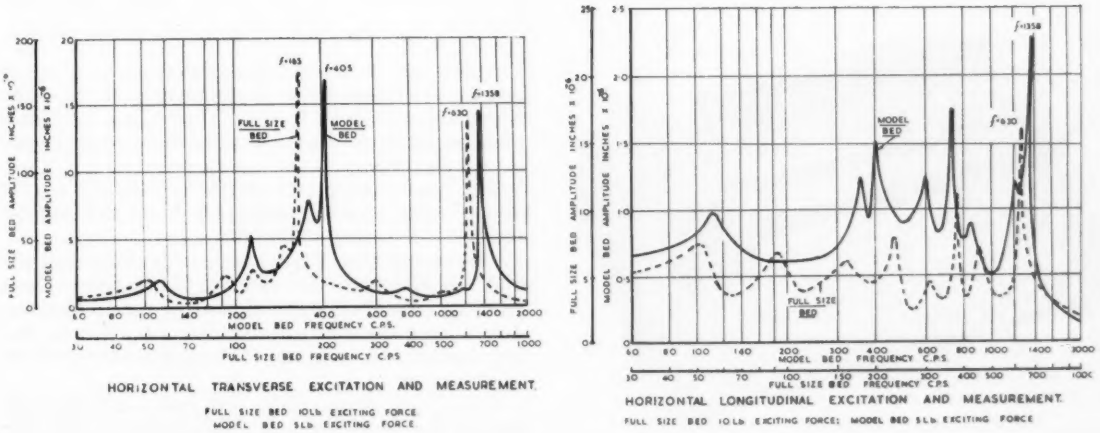

f=185
f=405
f=1358
f=1030
FULL SIZE BED
MODEL BED
MODEL BED FREQUENCY C.P.S.
FULL SIZE BED FREQUENCY C.P.S.
HORIZONTAL TRANSVERSE EXCITATION AND MEASUREMENT.
FULL SIZE BED 10Lb EXCITING FORCE
MODEL BED 5Lb EXCITING FORCE
HORIZONTAL LONGITUDINAL EXCITATION AND MEASUREMENT.
FULL SIZE BED 10 Lb EXCITING FORCE; MODEL BED 5 Lb EXCITING FORCE

Fig. 21. Static characteristic and frequency response of machine beds.

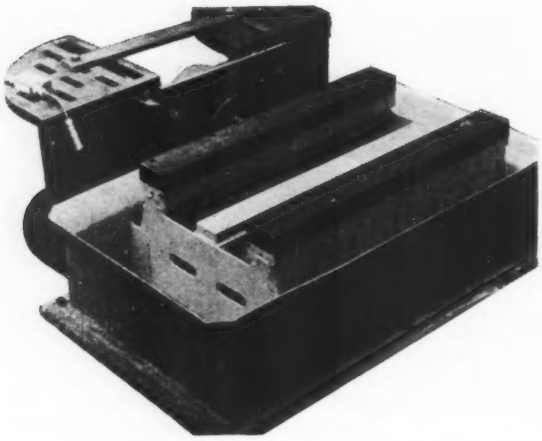


Fig. 22. Transverse excitation of model machine bed.

When the small vibrator was used for the excitation of the model bed, it was supported on two rubber pads from two heavy cast-iron bed plates, which were secured to the floor.

discussion of results

For full size and model of similar material, having the same value of Young's Modulus E, the theoretical deflection ratio y_1/y_s, should be equal to the length scale factor K, when the loading is applied according to the model laws of $W_1 = XW_s$ and $X = K^2$.

The results of the experiments with full size and model machine beds agreed with the scale ratios calculated from model laws. The deflection ratio of 2·2 compared with the model theory of 2·0 gave a difference of 10%, which was attributed to three welds on the full size machine, bed which were found to be cracked.

It has already been shown that the ratio τ of the natural frequencies of the full size and model must be equal to the length scale factor K. The ratio of the model and full size machine bed natural frequencies should therefore be equal to 2·0.

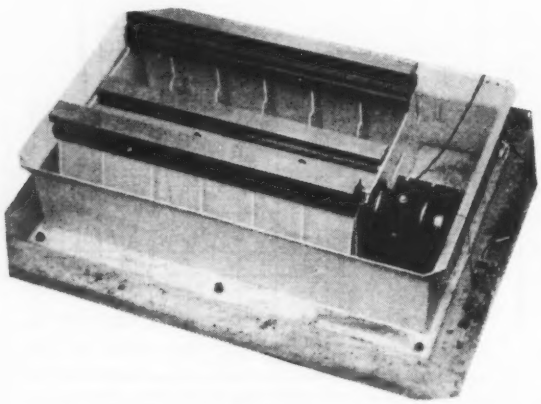


Fig. 23. Longitudinal excitation of full size machine bed.

The amplitude-frequency curves (Fig. 21) have been drawn for both machine beds when excited in the transverse direction. The scale of the frequency axis has been adjusted according to the model law, and the amplitude axis adjusted to accommodate the two curves. The different exciting forces for the model and full size give proportionally higher amplitude differences. For the full size machine bed, the first peak appeared at 53 c.p.s. and for the model at 115 c.p.s., a frequency ratio of 2·17, compared with the model theory value of 2·0. This peak would appear to be caused by the outer shell of the beds resonating.

In the case of the full size machine bed, the second peak occurred at 96 c.p.s., which was also the case when exciting this bed in the longitudinal direction. This was later proved to be caused by resonance vibrations of the trunnion mounting, which supported the larger vibration generator.

The transverse fundamental natural frequency of the full size machine bed occurred at 165 c.p.s., and that of the model at 405 c.p.s. This gave a model relationship of the frequencies equal to 2·4, the difference being 20%. This, however, would be expected in the particular machine beds investigated, since the full size machine bed had a lower static stiffness in the transverse direction due to a number of cracked welds.

Another peak of similar magnitude to the fundamental when excited in the transverse direction occurred at 630 c.p.s. in the case of the full size bed and at 1,358 c.p.s. in the case of the model bed. These frequencies coincided with the fundamental natural frequencies of the respective beds when excited and measured in the longitudinal direction.

In the longitudinal tests a number of resonant frequencies were excited in both machine beds. Fig 21 shows the amplitude-frequency response of the two beds in the longitudinal direction, the axes being again adjusted as in the case of the transverse curves Again, the lowest peak occurred at a frequency of 53 c.p.s. for the full size bed and at 115 c.p.s. for the model. The fundamental frequency of 630 c.p.s. for the full size bed and 1,358 c.p.s. for the model bear good relationship to the model theory. The ratio $\frac{f_s}{f_1} = 2{\cdot}15$ compares with the model theory of 2·0, a difference of 7·5%. The difference was again greater in the transverse direction because the welds which were cracked in the full size bed were in a position where they were stressed more when loaded in that direction.

The model theory was further confirmed by the other peaks which corresponded to the various members of the bed resonating.

The amplitudes of movement in both the full size and model beds were very small, therefore check readings were carried out measuring the acceleration direct from the pick-up and cathode follower, and the displacement calculated for the various frequencies of excitation.

In the case of the model bed, tests were originally carried out without the side rails bolted to the slide supports. This proved to have little effect upon the

static stiffness, since the slide-support bent more about the base plate of the bed than it deflected in its length. The addition of the extra stiffening member bolted to the top of the support rail only affected the deflection in the length of the rail, so that the model relationship for the stiffness measured in the transverse direction, with or without a stiffening member, still held good.

However, the frequency response without the additional mass of the slideways showed no relationship to the model laws, the transverse natural frequency being of the order of 600 c.p.s. The addition of the mass equal to the slideways mass of the full size bed, multiplied by the appropriate scale factors, reduced the transverse natural frequency to 405 c.p.s. This is certainly much closer to the theoretically expected value of 330 c.p.s., a value which in any case was known to be low because of the aforementioned cracked welds.

The result of this test proves again the extreme care which must be taken in the manufacture of the models if good results are to be obtained. Whereas static tests may show good agreement with the model theory, even if the models are not of exact geometric similarity, the dynamic behaviour cannot be relied upon unless the laws of model mechanics are meticulously obeyed throughout.

conclusions

It has been shown that with geometrically similar models and the aid of model mechanics, both the static and dynamic characteristics of machine tool elements can be predicted, within the limits of normal machine tool design.

In the static investigation, both under bending and torsional forces, the model laws have been shown to hold good.

In the dynamic assessment of the large and small beams, and also in the case of the actual machine beds which were examined, a satisfactory correlation of the natural frequencies as predicted from model theory was found. It is therefore reliable to predetermine the lowest natural frequency of single elements from tests carried out on geometrically similar models.

Extreme care must, however, be taken in the manufacture of models, both with respect to size and shape, if true model similarity is to be achieved. If geometric similarity is to be achieved the model dimensions must not be chosen too small, as otherwise difficulties may arise in maintaining the dimensional similarities in the manufacture of models.

The present work has been confined to single elements of machine tool structures. Further work is required to investigate the effect of bolted joints upon the model theory, and the overall static and dynamic characteristics of a number of assembled elements, especially with regard to damping effects.

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NOMENCLATURE

Symbol	*Quantity*	*Units*
A	Cross-sectional area	in.^{2}
b	Width of beam	in.
C	Modulus of rigidity	lb./in.^{2}
E	Modulus of elasticity	lb./in.^{2}
F	Shear force	lb.
f	Frequency	c.p.s.
g	Gravitational acceleration	386 in./sec.^{2}
h	Depth of beam	in.
I	Second moment of area	in.^{4}
J	Polar second moment of area	in.^{4}
K	Length scale factor	
k	Static bending stiffness	lb./in.
k_t	Static torsion stiffness	lb. in./radian
L	Length of beam between supports	in.
L′	Effective length of beam torsional natural frequency	in.
l	Overall length of beams	in.
l	"Suffix" denotes large beam	
M	Bending moment	lb. in.
m	Thickness of webs and flanges	in.
s	"Suffix" denotes small beam	
T	Torque	lb. in.
t	Time	seconds
W	Static load	lb.
	Weight of beam	lb.
X	Load scale factor	
x	Displacement x direction	in.
y	Displacement y direction	in.
y_B	Deflection due to bending forces	in.
y_{Sh}	Deflection due to shear forces	in.
α	Constant for particular cross-sectional shapes	
γ	Specific weight	lb./in.^{3}
θ	Angle of twist	radians
τ	Time scale factor	
μ	Mass per unit length	

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The Design and Development of the Rotary Compressor

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Mr. Coombes was educated at Eastbourne Grammar School and Eastbourne Technical Institute. After serving an apprenticeship with Howard Pneumatic Engineering Company, Ltd., Eastbourne, he was engaged on development work and technical sales. He joined Holman Bros. in 1929 and set up a Pneumatic Tool Drawing Office, where he worked on the design and production of pneumatic tools until 1946, when he was made entirely responsible for pneumatic tool design and development.

In 1952, Mr. Coombes was put in charge of compressor, hoist and haulage design and development, and earlier this year, was appointed to his present position.

Mr. Coombes presented this Paper to the Cornwall Section of The Institution of Production Engineers, of which he is the immediate Past Section Chairman.

IT would be well to commence this Paper with a brief history showing why and how this compressor was evolved.

Reciprocating compressors, and particularly those of the portable variety, have been with us for many years and, other than relatively minor developments, have not changed radically. At speeds of 1,000 - 1,200 r.p.m. the reciprocating compressor is quite happy but it has become slightly out of step with the modern high-speed diesel engine.

After the last World War the demand for compressed air equipment increased tremendously. In particular, the need for portable compressors of increased output was very evident. This was due to the use of much larger rock drilling equipment using more air per machine. Attempts were made to step up the previously largest portable compressor size from 300 c.f.m. - 500 c.f.m., and even to 600 c.f.m., but, owing to the low speeds of these machines, a very large, heavy engine was required and the sets were far too cumbersome to be termed truly portable.

Compressor manufacturers naturally sought a better solution to this and coincidentally, in 1947, Ingersoll Rand in U.S.A. and Major P. C. Bird in Britain patented the oil cooled sliding vane compressor.

Rotary sliding vane compressors have also been known for many years but, owing to certain inherent limitations, had not progressed very far. The use of oil as a cooling, sealing and lubricating medium gave them a new lease of life, however, and full advantage

was taken of the higher speed of the modern diesel engine. Thus a 600 c.f.m. portable compressor came into being, and it was no larger or heavier than some of the older, slow speed reciprocators of only half this output. Further than this, portable sets of 1,000 c.f.m. have now been put into service.

Users quickly became "rotary-minded" and appreciated the many advantages of decreased maintenance and increased mobility. Despite the improvement brought about by oil cooling, however, the sliding vane machine still retains some of its inherent weaknesses. These are mainly the effects of:

1. differential thermal expansion;
2. vane friction;
3. condensate in the lubricating medium.

Most compressor manufacturers followed the lead of Ingersoll Rand and Bird, and produced designs of sliding vane machines. Research carried out by the author's firm, however, revealed the fact that an alternative and more suitable type of compressor was required. It was decided that the compressor should:

1. be a rotary machine with a high-speed potential;
2. have positive clearances;
3. have positive displacement characteristics and built-in compression ratio;
4. be an axial flow machine;
5. be of simple design needing little maintenance.

The only design which appeared to fulfil these requirements was the Lysholm, invented by the Swedish gentleman of that name. The first patents were taken out in 1934 by the firm now known as Svenska Rotor Maskiner or S.R.M. Steady developments proceeded up to 1947 when the present lobe profiles were evolved and reasonable efficiencies obtained.

Licences have been issued to various firms in Europe and U.S.A. Some of these are:

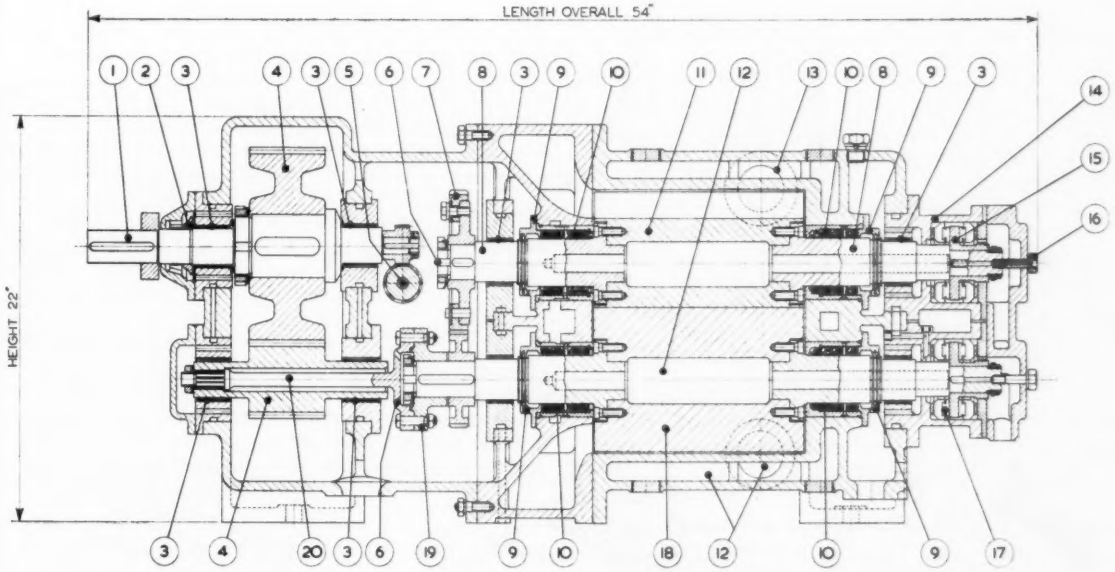
James Howden & Co. Ltd., Glasgow.
Gutehoffnungshutte, Germany.
Atlas Copco, Sweden.
I.R., U.S.A.
Fairbanks Morse, U.S.A.
Kobe, Japan

Holman Bros., Ltd. have an exclusive sub-licence from James Howden & Co. for a wide range of compressors both as to capacities and application.

Somewhat similarly to the "dry" sliding vane machine, the "dry" Lysholm compressor had been marking time, but with the introduction of oil cooling, it has now really come into its own.

the Lysholm compressor

The Lysholm compressor comprises two rotors, one described as female and the other male. They engage and roll together as a form of screw gear, but it must be appreciated that the female rotor has a form



1—DRIVING SHAFT
2—OIL THROWER
3—WHITE METAL BEARINGS
4—SPEED INCREASING GEARS
5—COUNTER SHAFT FOR OIL PUMP
6—COOLING OIL OUTLET
7—TIMING GEAR RIM & HUB
8—ROTOR STUB SHAFT JOURNAL
9—OIL SEAL
10—CARBON GLAND PACK
11—FEMALE ROTOR
12—COOLING OIL PASSAGE
13—COOLING WATER SPACE
14—THRUST BEARING HOUSING
15—THRUST COLLAR
16—COOLING OIL NOZZLE
17—TILTING THRUST PADS
18—MALE ROTOR
19—SHAFT COUPLING
20—QUILL SHAFT

Fig. 1.

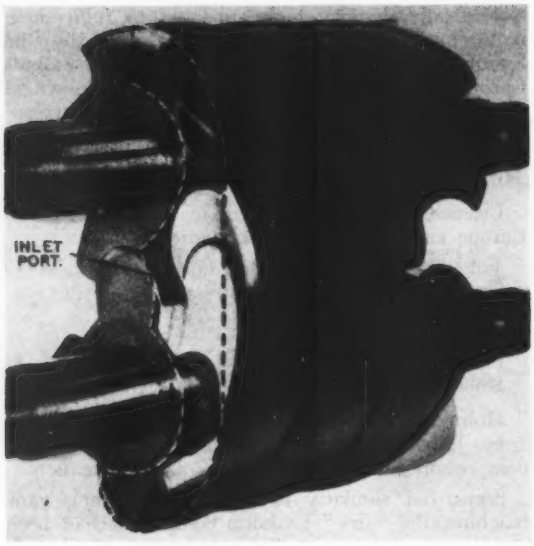


Fig. 2.

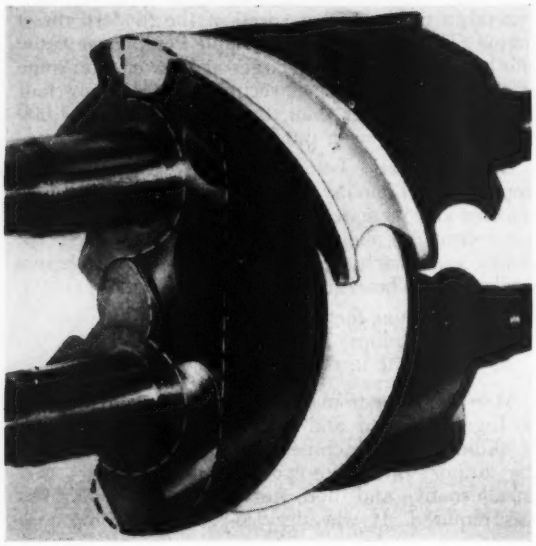
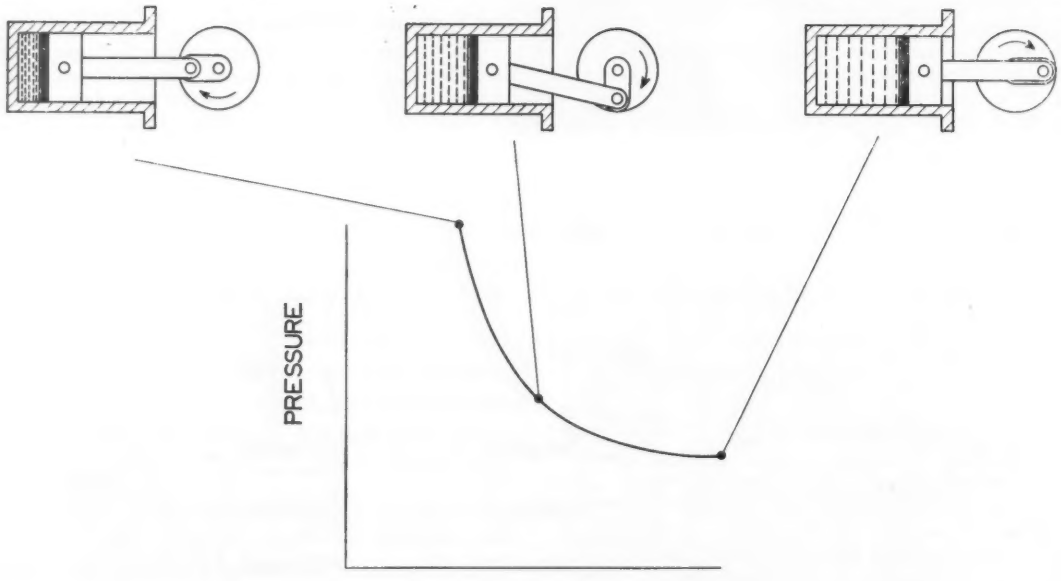


Fig. 3.



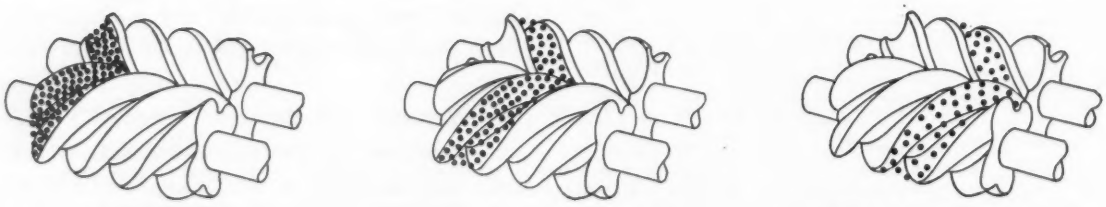


Fig. 4.

which is nearly all dedundum, whereas the male is nearly all addendum (Fig. 1).

The rotors are carried in plain white metal bearings and end thrust is catered for by Michel thrust bearings at the delivery end of the compressor. All thrust loads are in one direction, i.e., from the delivery end toward the inlet end. Carbon ring or labyrinth seals are fitted between the journals and the screws to prevent lubricant from entering the compression chambers. The casings have positive clearances around and at the ends of the rotors and timing gears are employed to phase the rotors in such a way that they do not touch each other. Step-up gears are enclosed in a gear box at the inlet end of the machine, as most prime movers do not run at a speed sufficiently high for maximum compression performance. From this description it is evident that this compressor covers the first two points in the design specification.

The normal maximum compression ratio for a dry machine is 3.5 : 1 although 5 : 1 may be employed, but with some detriment to reliability.

The working cycle of this machine is shown in Figs. 2 and 3. These views illustrate the suction part of the cycle. The rotors roll away from each other in these views so that each intermeshing pair of helical flutes in turn increase in volume and inspire air from the inlet port shown in dotted profile. For the purposes of illustration one pair of flutes has been marked in white.

Fig. 4 illustrates the compression part of the cycle and is likened to a reciprocating compressor in the upper views. From these illustrations it is obvious, therefore, that by varying the length of a given size of rotor and the position of the delivery port along the line of the cusp that a definite compression ratio can be built into the compressor. It is apparent that this is a positive displacement machine and that it has axial flow characteristics.

The mechanical complexity is very small, as there are so few moving parts and the need for preventative maintenance is, therefore, reduced to a very low order.

The foregoing briefly describes the so-called "dry" machine, which is normally cooled by the use of water jackets. The rotors are also often internally cooled by oil fed through the rotor shafts.

efficiency

There are two efficiencies which measure the aerodynamic performance of a "dry" compressor, namely, the volumetric efficiency and the adiabatic efficiency. The volumetric efficiency fixes the physical size of the compressor, whilst the adiabatic efficiency determines the driving power.

volumetric efficiency

The volumetric efficiency is usually defined as the ratio:

$$\frac{\text{VOLUME DELIVERED}}{\text{THEORETICAL SWEPT VOLUME}}$$

where the inlet volume is referred to inlet temperature and pressure and the theoretical swept volume depends on the size and speed of the machine.

The volumetric efficiency is usually less than 100% during filling since:

(a) the gas expands and, consequently, has a reduced density, due to:
  (i) throttling and aerodynamic losses; and
  (ii) to being heated by contact with the hot rotors and casings;

(b) gas leaks from the high pressure zones into the filling space thus occupying volume that should be filled with a fresh charge of gas.

Of these two factors affecting volumetric efficiency probably the latter has the greater effect.

adiabatic efficiency

The adiabatic efficiency is defined as the ratio:

$$\frac{\text{ADIABATIC POWER}}{\text{ACTUAL POWER}}$$

required to compress the gas to a specific pressure.

Jacket or rotor cooling extracts little heat from the gas being compressed, therefore, the cycle is more nearly adiabatic on a dry rotary compressor than is the case with a reciprocating compressor. The difference between theoretical adiabatic power and actual input power on the screw compressor includes pure aerodynamic losses, and also the work done on the gas which is lost owing to leakage.

losses

These are as follows:

(1) inlet loss

The inlet losses occur during filling of the flutes and they are made up from the throttling and skin friction losses and are assumed to be proportional to the mean inlet velocity head. $\left(\frac{\rho V^2}{2}\right)$

Since the inlet density is usually constant the inlet losses vary as the square of the inlet gas velocity, and this is proportional to the tip speed of the compressor. Therefore, increase in rotational speed results in an increase in inlet loss and, for any one tip speed, the pressure loss is constant.

The inlet loss is shown on the basis of efficiency in Fig. 5. Two tip speeds u_1 and u_2 are shown where u_2 is the higher value. From consideration of the inlet losses only therefore the adiabatic efficiency decreases with increasing speed over a certain optimum.

(2) leakage loss

The two rotors of a "dry" compressor do not touch one another, nor is there any mechanical contact between the rotors and casing. Small but positive clearances occur:

(a) between the meshing lobes, referred to as interlobe clearance;
(b) between the rotor tips and casing, referred to as tip clearance — these form a sealing line between the high pressure gas zones in the compressor.

Volumetric efficiency is a measure of the interlobe leakage only since the tip leakage is internal and,

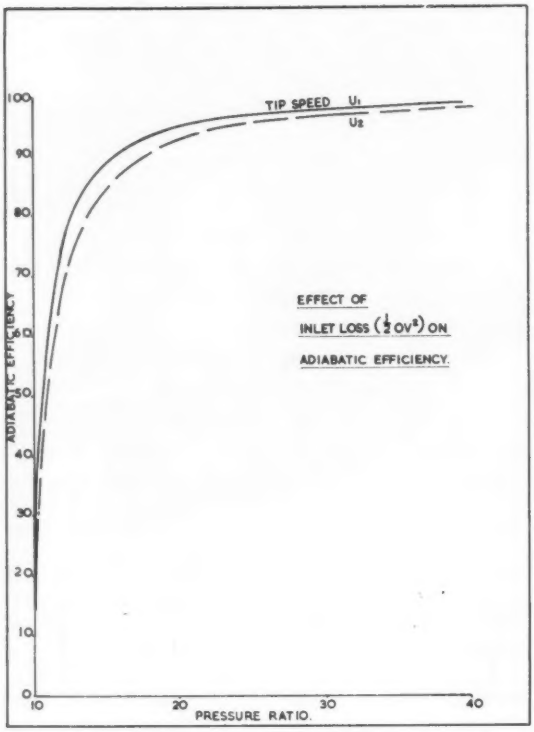


Fig. 5.

therefore, not measured. The factors affecting leakage are the clearances between :

(a) the male and female rotor tips and casing;
(b) the ends of the rotors and the high pressure end of the casing;
(c) the developed part of the trailing side of the leading male lobe and the tip leading edge of the leading female lobe;
(d) the tip of the female lobe and the root of the male rotor;
(e) the developed part of the leading side of the trailing male lobe and the tip trailing edge of the female lobe;
(f) the circular arc parts of the male and female lobes. (Fig. 6.)

(3) built-in compression loss

The lobe spaces of a "dry" compressor are filled with low pressure gas which is trapped in the lobe space during compression over the built-in pressure ratio, and then released into the outlet. The P-V diagram demonstrates the cycle (Fig. 7). The built-in pressure ratio is almost the same as the overall pressure ratio required at the design point and the outlet port is designed on this basis.

No matter, therefore, what outlet pressure of the compressor, the gas is always compressed internally, near to the design pressure ratio. It has not yet been found practical to make a variable outlet port. It will be appreciated, however, that any standard compressor can, by a simple alteration to the casting, have its outlet port made to suit any built-in pressure ratio.

When the outlet pressure is less than the built-in pressure ratio the P-V diagram is as shown in Fig. 7(c). The ideal work is A B E F but due to the built-in pressure ratio the work A B C G F has been done, so that E C G represents an unavoidable loss of work. Similarly when the outlet pressure is greater than design the P-V diagram is as shown in Fig. 7(a). The ideal work is A B E F so that the loss of work is E C G.

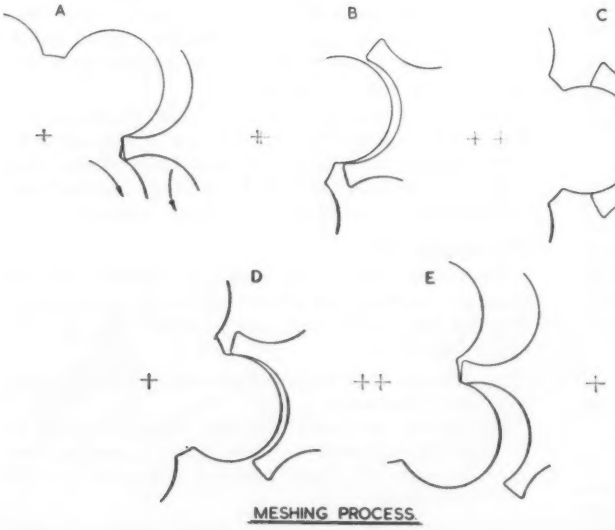


Fig. 6.

(4) outlet loss

With the outlet port correctly designed, the compressed gas flows smoothly from the lobes into the compressor outlet at the designed pressure ratio. When the outlet pressure is lower than the built-in pressure ratio, there is a sudden expansion as the gas is released to the outlet port, whereas when the outlet pressure is higher than the built-in pressure ratio there is a sudden compression. Thus in the first case, at the point of release, gas flows rapidly into the outlet until the pressure in the lobes is of the same magnitude as the pressure in the outlet pipe, and in the second case at the point of release gas flows back into the compressor from the outlet pipe until the interlobe pressure is the same as the outlet pressure.

The loss in the outlet port is taken as $\left(\text{Const.} \times \frac{\rho V^2}{2}\right)$ but since the density varies as the outlet pressure, the loss varies as $\frac{1}{\rho}$.

Typical outlet losses for the two velocities u_1 (300 ft./sec.) and u_2 (400 ft./sec.) are shown in Fig. 8. From consideration of the outlet losses only, therefore, the adiabatic efficiency decreases with increasing speed.

overall efficiency

The overall efficiency is based on these losses and the characteristics of the speeds u_1 and u_2 are shown in Fig. 9. As the speed increases from u_1 to u_2 the balance of the aerodynamic and leakage losses is such that the point of maximum efficiency moves to higher pressure ratios, due to the decreasing leakage loss and increasing aerodynamic loss.

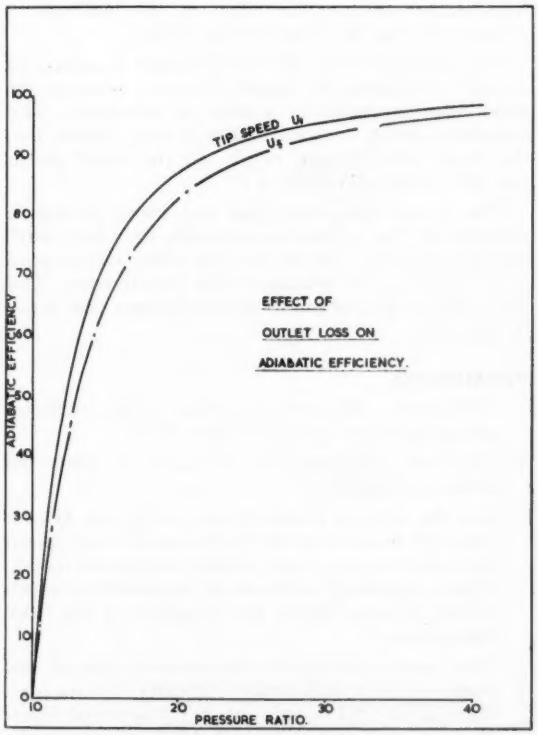


Fig. 8.

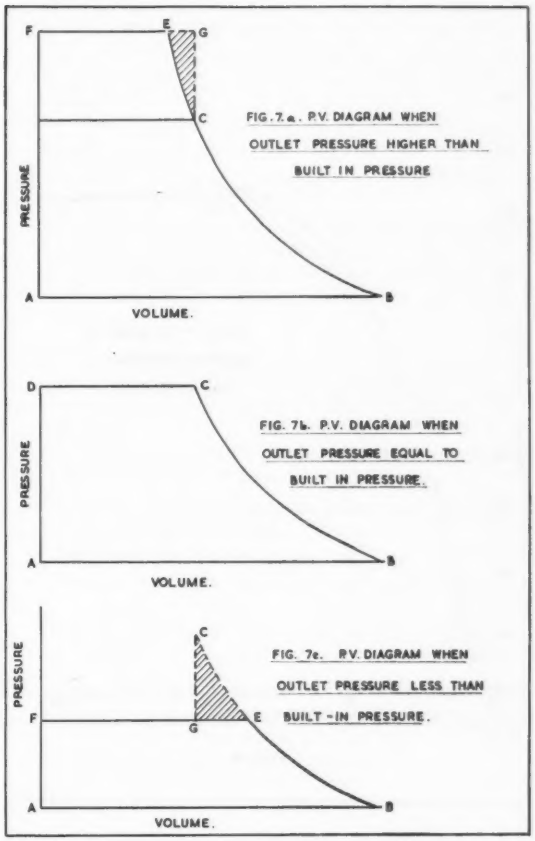


Fig. 7.

Fig. 10 shows the effect on the same compressor capacity of reducing the aerodynamic losses by increasing the wrap angle, and using short length/dia. ratios.

The wrap angle is defined as the angle the lobe turns through along the length of the rotor.

For these curves the leakage and built-in losses were kept constant.

design considerations

For a given volume, a compressor can have either :

1. a small diameter and a larger length/diameter ratio; or
2. a large diameter and a short length/diameter ratio;

the swept volume remaining constant.

For the maximum area of the inlet port and consequently lowest loss the largest practical

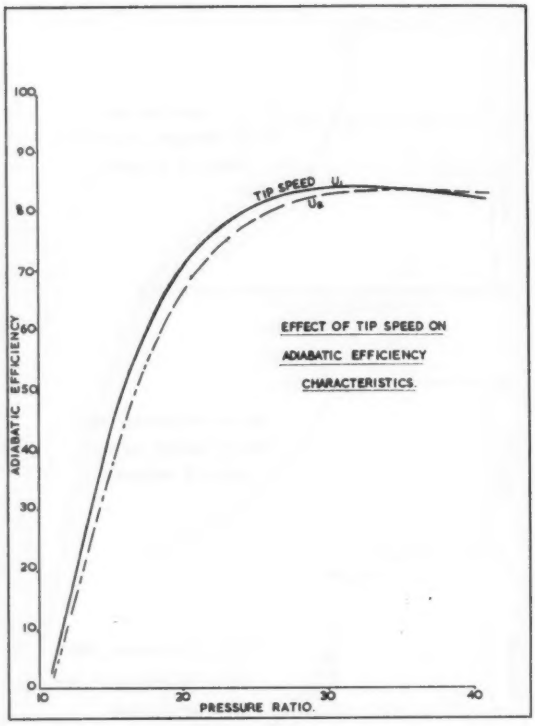


Fig. 9.

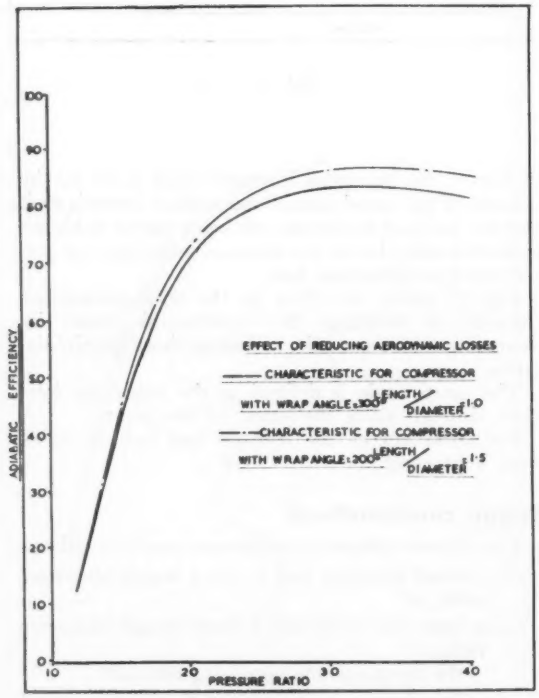


Fig. 10.

diameter is the best, that is the shortest length/diameter ratio. Similarly the same reasoning holds for the area of the outlet port and the outlet port losses. The tendency, therefore, is to employ short length/diameter ratios for highest efficiency.

One advantage of short length/diameter ratios is the reduction of the bearing loads, thus easing the mechanical design. Another advantage is that the stiffer, shorter rotors reduce deflection.

Theoretically 270° is the maximum wrap angle, since at greater angles the rotor spaces are not completely unmeshed at the outlet end before meshing recommences at the inlet end. With larger wrap angles, however, it is possible to employ larger ports and thus gain in adiabatic efficiency. An angle of 300° can, therefore, be used with advantage, i.e. :

(a) in a 370 c.f.m. compressor the rotors are 200 mm. dia. × 0.9 (L/D) and the wrap angle is 270°;

(b) in a 600 c.f.m. compressor the rotors are 200 mm. dia. × 1.5 (L/D) and the wrap angle is 300°.

Thus the rotors have the same end profiles but the longer rotors are required to handle a greater volume of air, and the increase of 30° wrap angle above the theoretical maximum is found advantageous.

The meshing of the rotors is shown in four views in Fig. 11. Here the rotors are viewed from the driving end and the drive transmitted via the male rotor. The arrows indicate the effect of the built-up air pressure during the compression cycle.

It is apparent that the female rotor is always in a state of balance as regards rotation, whereas the male rotor is always in a state of unbalance. This unbalance resists rotation and it is thus evident that the male rotor absorbs nearly all the input power and the female very little of it.

This is only completely true with rotors having no addendum. The addendum is usually only very small and the projected area of the addendum will create a small resistance to rotation of the female rotor. This is so small in proportion to the total power that it can be ignored.

conclusions

1. Volumetric efficiency increases with increased rotational speed up to a certain limit.
2. Adiabatic efficiency is decreased by increased rotational speed.
3. For the normal prime movers a step-up gear is required to achieve the higher compressor speeds and this results in high pitched mechanical noises. It also introduces mechanical complications which off-set to some degree the simplicity of the basic compressor.
4. The maximum built-in compression ratio in one stage is 3.5 : 1; this clearly indicates that for pressures of 40 P.S.I.G. upwards two stages with intercooling are necessary, which tends to negate the basic simplicity of the Lysholm compressor.

5. The temperature of the delivered air is fairly high. This creates problems of differential expansion and, in fact, there is a considerable difference between cold and hot clearances. The clearances are normally referred to in the hot state.

effects of injection oil cooling

The introduction of injection oil cooling has considerably altered the situation regarding this type of compressor.

No form of jacket cooling is employed and no attempt is made to cool the rotor internally. Instead, a relatively large quantity of oil is injected into the compression spaces shortly after the inlet port is closed, and this becomes intimately mixed with the air, carried through the compressor and delivered into a storage vessel.

The oil so injected has a threefold function:

(a) sealing leakage paths;
(b) cooling;
(c) lubrication.

The effect of:

(a) is to so raise the volumetric efficiency as to enable the rotational speed to be considerably reduced for any specific output. Tip speeds varying between 100 ft./sec. and 150 ft./sec. can now be employed instead of 300 - 400 ft./sec. and compression ratio up to 10 : 1 in one stage.

(b) Continuous cooling makes it possible to reduce the heat rise and very low delivery temperatures are possible by the use of a suitable size of oil cooler.

The compression is, however, more nearly isothermal than is the case with a dry compressor with the consequent improvement in efficiency.

This relatively small temperature rise results in only very small changes in clearance conditions and these clearances can, therefore, be reduced. This reduces leakage losses still further.

(c) Lubrication where it is required is on such a generous scale that wear is negligible. This is also materially assisted by the fact that the oil is cool.

The overall effect is to raise the volumetric and adiabatic efficiencies because of:

(a) less gas expansion at inlet due to cooler rotors and casings;
(b) lower losses from back leakage;
(c) smaller inlet loss due to lower rotor tip speed;
(d) smaller delivery loss due to lower rotor tip speed.

This innovation results in a much simplified design of compressor even when taking into consideration that we now need only one stage to obtain a compression ratio of 10 : 1.

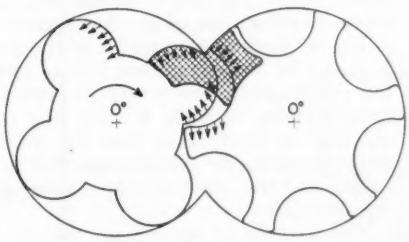


Fig.1

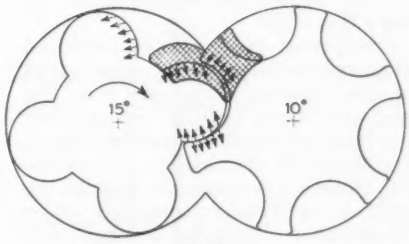


Fig.2

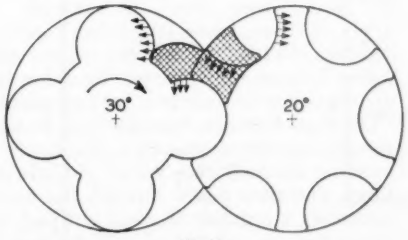


Fig.3

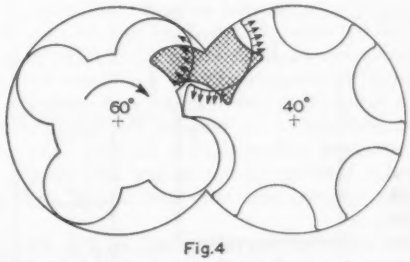
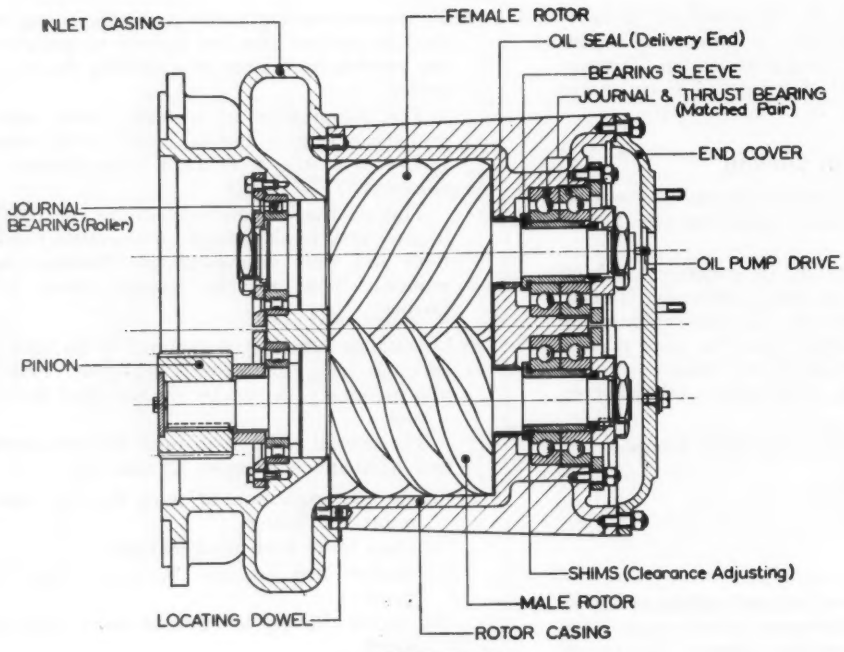


Fig.4

EACH ARROW REPRESENTING EQUAL FORCES THE BALANCING EFFECT ON THE DRIVEN FEMALE ROTOR OFFERS NO RESISTANCE TO ROTATION. THE FORCES ON THE MALE ROTOR ARE SUCH THAT IT IS ALWAYS UNBALANCED AND CREATES GREAT RESISTANCE TO THE DRIVING FORCE. THIS ARRANGEMENT RESULTS IN A CUSHIONED, IMPACT FREE, ALMOST FRICTIONLESS DRIVE.

Fig. 11.



ROTAIR 370
ROTORS 200 m/m Dia. x 180 m/m Long.
(7·874 ins Dia. x 7·086 ins Long.)

Fig. 12.

The rotational speeds now come within the range of conventional ball and roller bearings and the arrangement is much less complicated than the plain journal and Michel thrust type employed in the "dry" compressor (Fig. 12).

Each rotor is supported by a pair of combined journal and thrust ball bearings at the delivery end and a standard roller bearing at the inlet end. The combined journal and thrust bearings are matched and fitted back to back, providing accurate location of the rotors. Being placed at the delivery end of the machine the fine clearance between the ends of the rotors and casing is accurately maintained under all conditions of operation. The roller bearings allow expansion to take place freely and this is taken care of by the large clearance at the inlet ends.

No close fitting or complicated seals are employed, but a simple bronze sleeve is fitted at the delivery end of each rotor, into each of which oil is injected to prevent escape of compressed air. The same oil is employed for lubricating the bearings and cooling the compressor, and minor oil leakage through the seals becomes an asset rather than a liability. The step-up gear ratio between prime mover and compressor is greatly reduced and only one pinion and gear are required.

The oil circuit is shown diagramatically in Fig. 13. The oil is drawn from the oil storage tank and pumped through filters into a cooler. From there it passes into a distribution system. The main body of the oil is injected into the compressor and the remainder is deflected to the bearings, delivery end seals and driving gears. The oil supplied to these gears drains into a sump in the gear casing and from there it is scavenged back into the main injection circuit again. The rate of circulation is one gallon for every 20 cubic feet of air compressed.

The oil circulating pump is of the rotary type and is driven by the compressor female rotor. There are two star-shaped rotors fixed on a common shaft, each rotor rotating within a floating ring which contains one lobe or tooth more than the rotor. One of the rotors provides the coolant injection and lubrication supply and the other acts as a scavenge pump from the gear case.

The process of reclaiming the oil after passing through the compressor is as follows. The compressed air heavily laden with oil is delivered by pipe into the oil storage vessel. The angle of entry, being tangential, causes much of the sensibly solid oil to fall out of the air which then passes into an upper vessel. In doing so it is baffled at two points to remove a further quantity of the oil.

The final filtration equipment is housed in an inner tubular member contained in the upper vessel. Before entering the final stage the air changes direction three times, and then passes through the filter pack which comprises a number of absorbent pads with drainage points between each pad. All the neat oil recovered from the initial stages returns to the lower storage vessel, but that recovered from the final filtration returns to the inlet of the compressor. This is due to the fact that in passing through the packs there is a slight pressure loss. Control of output according

to demand is carried out by means of strangling the inlet of the compressor. An inlet valve is controlled by a mechanism which responds to pressure fluctuation in the service mains, and causes the valve to obstruct the inlet to match supply to demand.

Two pressure lines are fed to a flexible bellows on the end of which a needle valve is attached. One feed to the inside of the bellows is at a controlled pressure pre-set by a regulator. The other line enters the closed chamber surrounding the bellows. Whilst the latter is at a lower pressure than the former the needle valve closes the port leading to the inlet strangler valve. When the demand for compressed air decreases the outlet pressure increases; the pressure outside the bellows increases until it is sufficient to overcome the controlled pressure inside the bellows. Thus, the needle valve progressively admits more air on to the piston end of the strangler valve to move it gradually to the closed position.

When diesel engine drives are employed this control slows the engine and compressor speed down progressively until approximately half full speed. The unloader valve commences to close the inlet at approximately two-thirds full speed and continues its movement after the minimum speed has been reached until full closure, when complete unloading is obtained. In the case of electric drives, inlet strangling is applied at constant speed.

The most compact form of installation is when the compressor is flange mounted on to the prime mover.

A further step forward in the design of the compressor has been made and is applied to the smaller sizes only at the moment. The larger machines will be brought into line in due course. In this the separate oil storage and recovery vessels have been eliminated and they have now been integrated into the basic compressor in the form of cast casings surrounding the rotors. In effect the compressor has been inserted into the oil storage tank. This reduces the bulk and weight considerably and dispenses with a number of outside pipes and associated work. Other effects are rapid warm-up, as the heat from the compressor is more rapidly transferred to the oil which is surrounding it, and the maintenance of operating temperatures at a more constant level during normal operation.

HOLMAN ROTAIR OIL CIRCUIT

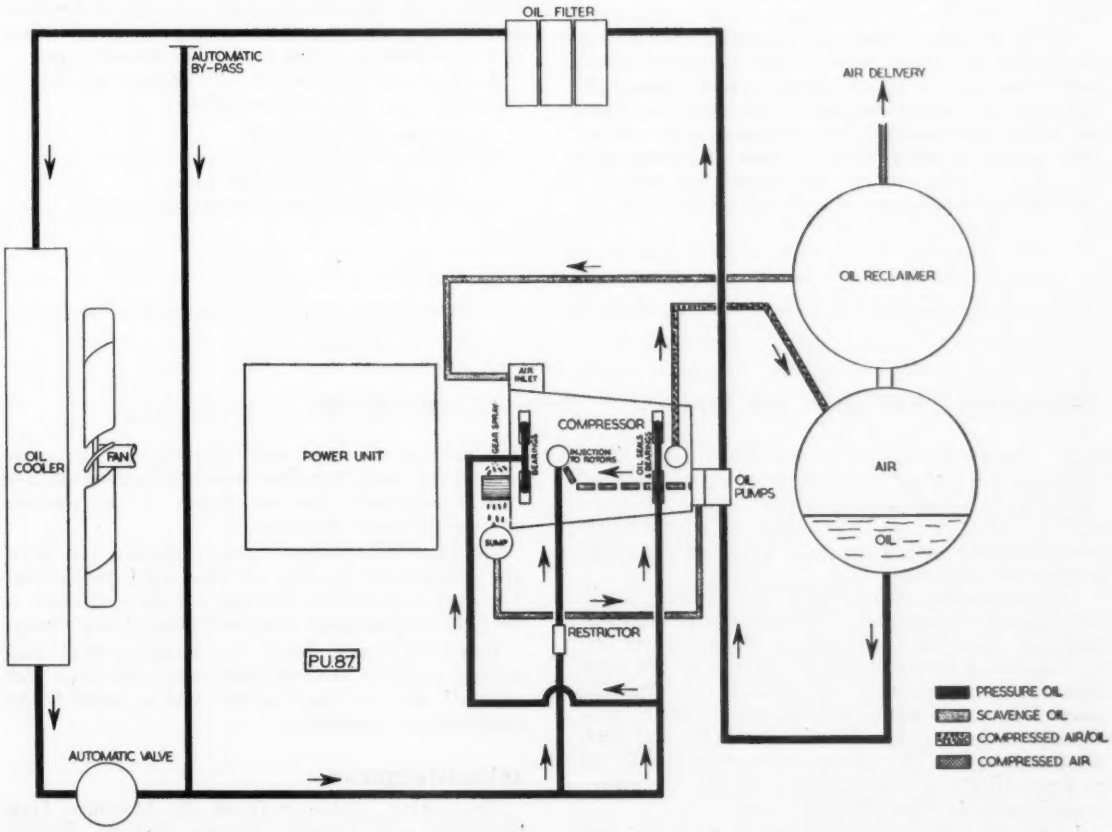


Fig. 13.

Fig. 14.

Finally, a few points regarding other ancillary equipment. Both the engine and compressor units are protected by instruments which shut down the engine immediately, if called upon to do so. A comprehensive range of instruments is contained in one panel.

During the whole time that the machine is running, the engine fuel pump lever is kept in the maximum fuel position by an electrically energised solenoid. In the event of a fault occurring, the protection switch in the system involved will close the protection circuit. This operates a relay which in turn will de-energise the solenoid acting on the fuel pump, thus stopping the machine. The system at fault will be shown on one of the indicators. These indicators are spring loaded but will latch in the working position under normal conditions. When the cause of the fault has been rectified the indicator is returned to the "normal" position before the engine is restarted.

The compressor is protected against oil failure by a pressure switch. The engine is similarly protected against oil pressure failure and in addition any undue heat rise in the cooling system operates a thermal switch.

The chassis is mounted on four independently sprung wheels and incorporates automotive type steering. This permits a degree of mobility hitherto not possible with this type of equipment and in fact towing speeds of 50 m.p.h. are not unknown.

The smaller machines are mounted on a two-wheel chassis, the axle having torsion bar springing independently on each wheel. The chassis of these smaller machines is made of rectangular tubular members, the drawbar being integral with the main members. The enclosures are of moulded fibreglass suitably reinforced. This makes for maximum lightness coupled with good accessibility.

conclusions

This rotary compressor is the result of several years of intensive research, development and testing. A certain stage has been reached at which it has been possible to produce a type of rotary compressor which is a considerable advance on other known types.

Further development is still going on and in particular we can look forward to:

1. increased efficiencies;
2. higher outputs from specific rotor sizes;
3. increased output/weight ratio;
4. cooler, cleaner compressed air.

"Computers — Retrospect and Prospect" —concluded from page 562.

legal actions automatically initiated and issued. Payroll, which is currently the most popular industrial application, will fall into a natural decline; its place will be taken by the scheduling of maintenance, power supplies and spare parts for electronic data-processing equipment.

The computers of the future will be very small, very fast and very powerful. Only very large organisations will have one to themselves. A few others will be installed at central bureaux to satisfy all the lesser demands on an automatically time-shared, time-hire basis. Data and results will be automatically continually exchanged between the computer and each of the customers. An invoice will automatically be sent periodically to each customer for the few microseconds actually occupied by his work.

Eventually computers will come to work out and execute a national economic policy. The Bank Rate and the various taxes and subsidies will vary continually by small amounts in order to forestall and correct accurately forecast trends in the national and international situation.

Computers will compose almost all music and literature and decide the issue of most legal proceedings. The data transmission channels will hum annually in the fight for the world electronic chess championship.

It is to be hoped that in the course of time, most human activities and incompetences will have been replaced, and we shall be left with a world fit for computers to compute in.

acknowledgment

The author, wishes to thank the Manager, Data Processing and Control Systems Division, English Electric Co. Ltd., for permission to publish this Paper.

COMPUTERS — RETROSPECT AND PROSPECT

by G. M. DAVIS, M.A.

A Paper based on an address given to the Convention on "Computers in Industry" organised by the Birmingham Graduate Section of The Institution of Production Engineers in September, 1960.

IT might be said that the first machine with all the essential characteristics of the modern electronic digital computer started to work at Cambridge University in 1949; however, the definition is not a very clear one, and there are several slightly earlier claimants to the title. Apart from this, there are many other types of computer, mostly of much earlier origin; for the purpose of this Paper, the term "computer" will be taken to mean electronic digital computer in the accepted modern usage.

It will be seen that the history of computers in our chosen sense is very short; a great deal has happened in this time. Several new professions have grown up, each with its own mass of literature. The early laboratory models have become the basis of a flourishing industry.

Computers have become essential tools for several industries and fields of scientific research. Apart from their application to all kinds of computation, they are now widely used for large scale clerical operations in industry, commerce and Government departments. Further possible fields of application are being investigated, for example, in language translation and medical diagnosis. Techniques are being developed in which the computer operation resembles higher human activities such as learning and intelligent problem solving, rather than merely execution of predetermined rules.

There has also been great development in the computers themselves. Speed of operation, for example, has increased by a factor of more than 50,000 and the earliest computers were already so fast that leading authorities thought that three or four would satisfy the computing needs of the whole country.

The main object of this Paper is to give those comparatively unfamiliar with the subject some indication of the kind and scale of the development which has taken place; a number of the more important fields of activity will be traced in turn from the beginning of computers to the present position, with some indication in each case of the most recent developments and those immediately ahead. The intention is to give a graphic impression of each topic covered rather than a precise detailed account.

It would be rash to foretell the future further than two or three years; those most qualified to judge are by no means in agreement. However, a not-too-serious sketch of some of the longer-term possibilities will be given in conclusion.

The main approach is from the point of view of activities in Britain, though there are passing references to work in other countries.

the general development of computers

The first computers were designed and built in the laboratories and universities and Government departments. They had been made possible by the great advance in electronics during the last War.

However, computers made demands on reliability far beyond those of radar; a computer would be almost useless if one operation in one hundred million were incorrectly carried out. For some time it was questionable whether they would ever work effectively. Eventually, the first laboratory computers came into operation, and many of them did a great deal of useful work for several years. The standard of reliability was higher than might have been expected, though it did not approach that required and achieved in modern computer systems.

Production versions of these laboratory models were then marketed by manufacturers working in liaison with the laboratories which designed them. This was the basis of most British computer production up to about 1956. Since then, manufacturers have been designing their own computer systems, and there are now eight or nine British firms marketing systems they have designed themselves.

The early applications were in scientific, mathematical and engineering computation. More recently, the emphasis has been on large-scale data-processing for commerce, industry and Government. This type of work demands a rather differently organised computer, and later computer designs have taken this into account; instead of the "computer", one now has the "computer system" or 'data-processing system".

Systems have generally got larger as well as more powerful over the years, for several reasons. Apart from the competitive expansion of manufacturers' ideas, users have been led by existing facilities to tackle ever larger problems, and computers are expected to cover increasing areas of work within a given organisation; another reason is that a given piece of work is generally done more cheaply on a fast, large system than on a cheap slow one. Almost every British manufacturer has announced as currently under development a system larger and more powerful than anything they have had before. There are also systems nearly complete in America and one under development in Britain which are several times larger, faster, more powerful and more expensive again.

As well as this trend towards ever larger computers, there are interesting developments in much smaller systems; these are mainly intended for various types of industrial application and for acting in an auxiliary capacity to the larger systems.

Although it happened that one or two British computers came into operation first, the Americans were very close behind. Their computer industry has grown extremely rapidly, and their number of installations is now measured in thousands compared with the two or three hundred in the United Kingdom. Various causes have been attributed to this discrepancy, including a vast American Government expenditure on research and equipment, and the

Mr. Davis, seen here at a computer console, went to University College School and read mathematics at Trinity College, Cambridge. During the War, he worked on radar circuit development at TRE, Malvern.

He has been with English Electric on computers since 1950, when he joined the team of engineers and mathematicians working with the National Physical Laboratory on the development of the Pilot ACE. After this, he set up and ran for a time the English Electric Computing Service in London.

He has worked on most aspects of computer design and application and acts now mainly as a consultant and on internal and external liaison.

Mr. Davis is a member of the Council of the British Computer Society and has taken part in the considerable recent B.S.I. activity on Data Processing.

Fig. 1. The EDSAC I Computer at Cambridge University Mathematical Laboratory (since replaced with EDSAC II).

comparative readiness of American industry to try something new. The fact remains that the scale of American effort on all aspects of computer activity now greatly exceeds our own.

A number of other countries now have computer industries and activities, but these are mostly smaller than our own. Japan, in particular, has contributed a number of valuable developments in computer components.

Russia has a good deal of activity and has produced a number of different computers, but from available information seems to be some way behind America.

This brief survey has been mainly concerned with the equipment itself. Other fields of activity are considered in subsequent sections.

components

It has been mentioned that computers have greatly improved in speed and reliability. Part of this improvement has been due to improvements and developments in the basic components from which they are made.

Some of these developments have been in response to computer requirements, but some have come from other branches of electronics. An example of this is the universal adoption of the transistor in place of the valve; this has given improvement in reliability, size and power consumption.

However, the fastest transistor circuits are only about 20 times faster than the fastest valve circuits used in the early computers. Components of much higher intrinsic speed are required. A variety of fast switching devices are under development, but are taking rather a long time to complete. These new devices will generally take two or three thousandths of a microsecond for a basic switching operation, and will provide computers 50 to 100 times faster than the fastest now available.

To take just one example, the Parametron, or parametric oscillator, which was invented in Japan, may be adapted to switch and combine signals in the form of very high frequency oscillations. Such signals are normally carried in waveguides rather than on wires; this might suggest that computers of the future would be constructed by plumbers rather than by electric wiremen.

It should be mentioned in passing that the distinction between switching components and storage components is not always clear cut. For example, parametrons may be used for storage as well as switching, and the Cryotron, quoted in the next section as a storage device, may also be used in switching circuits.

If still faster computers are to be made, they will have to be remarkably compact physically, for no signal can travel further than one foot in a millimicrosecond, this being equivalent to the speed of light. It is sometimes suggested that this consideration will soon impose an ultimate limit on speed of operation; however, there is ground for hope, since far lower forecasts of ultimate speed have been made before, for reasons which seemed equally valid at the time.

storage

An essential part of a computer is the store, which holds the program of instructions specifying the job to be done, the initial data and the intermediate and final results.

Various kinds of device have been used for storage; the important characteristics of a storage mechanism are the speed with which data can be got in and out and the cost per unit of data stored. Faster stores tend to be more expensive, and many computers have two or more levels of store to balance the cost; there might be a fairly small, fast, expensive type of store in continuous use, and a larger, slower, cheaper "backing store" from which the fast store would be periodically recharged.

An early form of high-speed store was the cathode-ray tube, which stored digits as spots of electric charge on its surface. Another was the delay line, in which a succession of pulses representing digits were stored

by being trapped in a recirculating path including a delay.

The high-speed storage mechanism of almost all modern computers is the magnetic core. This is a small toroidal piece of magnetic material in which a single binary digit is represented by the direction of residual magnetisation after a magnetic field in one or other direction has been applied. While the magnetic core is the best currently available general-purpose high-speed storage device, it has some disadvantages. These include a limited speed of operation and the rather large amount of power needed for its operation.

A number of newer devices which should overcome these disadvantages are under development but none has yet reached the stage of practical application. These new types of store will have access times of a few millimicroseconds. They include, for example, the Cryotron, a device based on the superconductivity phenomenon and requiring to be maintained at just above absolute zero temperature.

For the slower stores, the magnetic drum is a very popular device which has survived from the earliest to the latest computers. It consists of a rotating drum on a surface of which digits are written as dots of magnetisation.

Some types of data-processing application require access at very short notice to any item from a large collection of data, say from two or three million items of ten letters each within one-tenth of a second. Several devices have been made to meet these requirements for "Random Access Storage" as it is sometimes called; most of these devices have a number of rapidly-moving mechanical parts and generally give the impression that there must be a better method; so far no one has found it. A well-known example is the RAMAC, known popularly as the "jukebox", in which data is recorded magnetically on the surface of any of a stack of rotating discs.

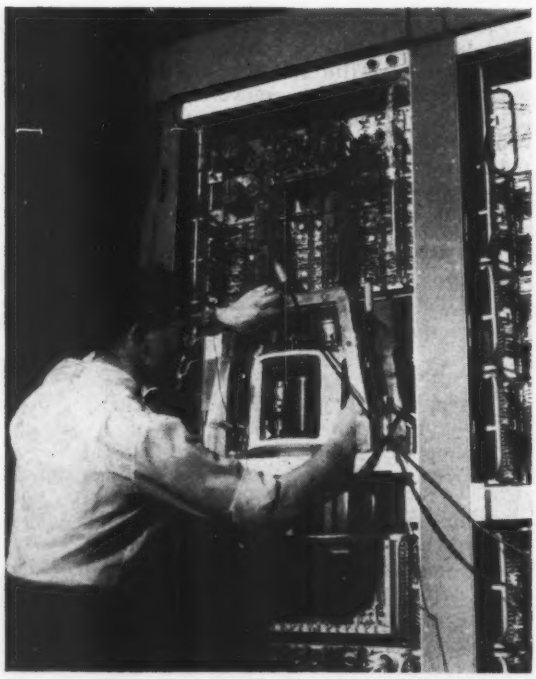


Fig. 2. The magnetic drum store of the English Electric DEUCE Computer.

magnetic tape

Magnetic tape has been used on computers for some years. Probably the first working tape was on the Remington-Rand Univac in about 1952. The mechanism is basically similar to that of an audio-frequency tape recorder, though both the tape and the mechanism have to meet much stricter performance requirements.

As on a magnetic drum, data is recorded as dots of magnetisation, each dot representing a binary digit. The width of the tape accommodates a row of several such dots, usually about seven. In the early tape mechanisms, the rate of reading or writing data was usually about five thousand of these seven-bit rows per second. This rate has generally increased by a factor of about 10, and has been further increased by such stratagems as using wider tape and writing more digits across it. Very much higher speeds have been achieved under laboratory conditions and may soon be available for general use.

Magnetic tape may be regarded and used either as an input and output device or as a large-scale store. It is most useful in applications where it is convenient to accept and deal with the items of data in a fixed order, the order in which they are stored on the tape. Fortunately, many scientific and data-processing applications can be planned to work in this way. Tape is a very inefficient store in cases where access is required at random to any item of data, and it was for these applications that stores such as the RAMAC were developed.

input and output

In the early computers the input and output of data was considered a secondary problem. Well-tried punched card and punched paper tape devices were directly adapted from existing systems. The computers were intended to perform long calculations with comparatively little initial data and final results.

Many computers, for example, including production models, did a great deal of very useful and effective work with a paper tape punch at about 25 characters per second as their sole output device. The slowness of the output, compared with an internal capacity for producing a thousand or more 10-digit results per second, was regarded as only a minor inconvenience.

As computers have increased in internal speed and have developed into data-processing systems intended to perform a large number of simple operations involving a mass of data and results, input and output of data has provided several major difficulties.

The first difficulty is that the essentially mechanical peripheral equipment has not kept pace in speed or reliability with the electronics. If one considers for example, a printer operating at a 1,000 lines per

minute of 150 characters each and requiring a separate mechanical action for each character printed, the difficulties become apparent.

One approach to this problem is to accept the comparatively slow working of ultimate input and output devices, and to adopt stratagems to prevent them from slowing the central processing device; these will be discussed later.

A complementary approach is to reduce the number and speed of moving parts. One example of this approach is the Xeronic printer. A very rough description of its operation is that characters to be printed are formed on a cathode-ray tube and focussed to make a corresponding pattern of electric charge on a rotating drum; charged, inked particles are then made to adhere to the drum and the resulting pattern is pressed on to paper. The Xeronic will print up to 3,000 lines per minute; a selection of standard forms can be printed on the same paper at the same time as the data. Apart from its speed, the development promises considerably higher reliability than that of mechanical printers, and is a quoted feature of most current British data-processing systems.

A second and most important class of difficulties is that of getting data into an electronic system without an expenditure of time, effort and financial cost far out of proportion to that required by the system itself. For example, to make a manual key depression for every character to be input occupies a great deal of time and human effort; this is sometimes unavoidable, but there are many situations in which the labour can be avoided or reduced.

One stratagem is to use key depressions already being made for another purpose; for example, cash registers are available which automatically copy each till-roll entry as it is made on to punched paper tape. These paper tapes can then provide the raw material for accounting procedures for a department store or chain of shops.

Dual-purpose documents are coming into wide use. The mark-sensed card is a familiar example. Another is the cheque carrying "marking" in a special magnetic ink as well as printed and written information. The cheque is issued to the customer carrying magnetic data on his account and branch number; on return, the signature is checked and the amount and date are typed in manually in magnetic ink; the cheque is then a complete input document for an automatic system. The magnetic "marking" may either be separate from any printing and arranged in a code suitable for unambiguous automatic reading, or it may consist of the printing itself which is done in an ink containing magnetic material.

The requirements for keyboard operation would be greatly reduced if it were possible to read automatically ordinary printing, typing and even handwriting. Optical character recognition systems have been under development for several years, and are reaching the stage where they could be applied in normal everyday use. They are confined to printed and typed material, and handwriting has not been seriously tackled, though there is some interesting research going on. The ideal is a system which will

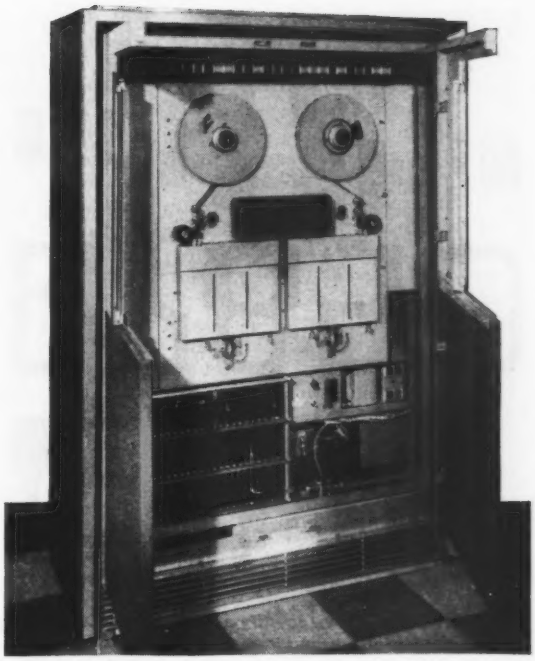


Fig. 3. A magnetic tape unit, based on a design by Radio Corporation of America. The tape passes at 100 inches per second and carries 333 characters per inch, giving a transfer rate of about 33,000 characters per second.

recognise all the letters, numerals and punctuation symbols from any type face. However, it will be clear that the finer the distinctions to be made, the more complex will be both the logical analysis of differences in character shape and layout and the equipment required. Some of the systems being developed recognise only the numerals, and these must be printed in a special type face designed as a compromise between human and machine legibility; these have a valuable contribution to make in certain types of application but clearly fall short of the ultimate requirement.

Equipment is also being developed for the physical handling of documents, particularly in connection with character recognition. For example, automatic sorters are already in use which handle cheques in mixed sizes and shapes.

In all these developments, an important element is the relationship between the cost of the equipment and the financial return it may be expected to make in use.

Other developments in input and output equipment provide for the input of various types of meter reading and output in the form of control signals to continuous process plant, machine tools and material assembly systems. Direct visual outputs in the form of graphs and other displays are also used in some applications.

Together with these newer forms of input and output, the conventional forms have been made somewhat faster. Card reading speed has increased from

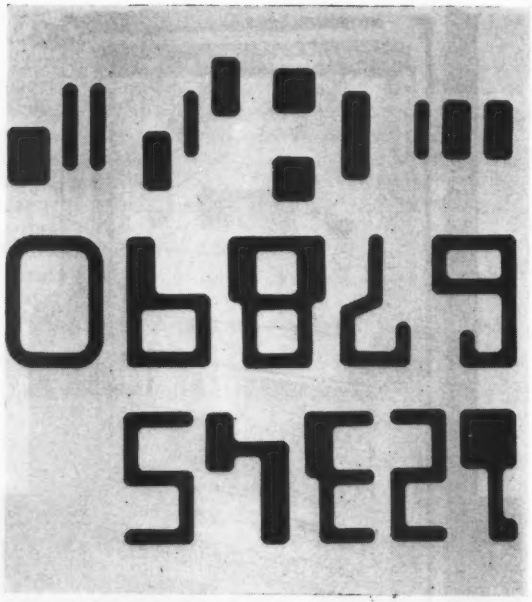


Fig. 4. E13B Typeface, recently adopted as a standard by British banks for printing in magnetic ink. The characters, which comprise the numerals and four control symbols, are designed as a compromise between human and machine legibility.

200 cards per minute to 400 or in some cases 800; punching from 100 to 150 or 250. Standard punched paper tape speeds have increased from 200 characters per second in and 25 out to 1,000 in and 300 out.

data transmission

As data-processing systems grow larger, and are applied to wider areas of work, operations tend to become more centralised. A chain of shops, an insurance company, or a manufacturing organisation may have a central data-processing system which needs very rapid and reliable communications with widely-spread local offices. This would most conveniently be achieved by sending signals along wires connecting the various centres; however, existing facilities for data transmission, for example standard telegraph lines, are generally inadequate for these new requirements.

The problem is currently receiving quite a lot of attention. Research is going on into rates of transmission required, coding systems for detecting and correcting errors, and into transmitting and receiving equipment. International meetings have discussed standardisation and progress in development.

Adequate facilities begin to be made available, but there are some formidable technical and organisational difficulties to be overcome. There has been a good deal of progress since the delivery of this Paper in September, 1960.

As in the case of input and output equipment, the economic aspect is very important; the equipment produced must not only be fast, convenient and reliable, but also be not unduly expensive to install and operate.

the logical organisation of computers

The internal structure of the early computers — their instruction codes, arithmetic operations, store sizes, number lengths, and generally the way signals were combined together to generate the operation of the computer—were designed by electronic engineers and mathematicians.

In these days, there are professional Logic Designers, whose job is to design the way in which the components and circuits produced by the engineers may be combined together into complete systems; several large books have been devoted solely to Logic Design.

This is specialist work of little direct interest to the user. However, it may be worth considering some of the ways in which the structure of computers has developed; this has contributed quite as much to the enormous improvements in performance as developments in component and circuit design.

The first place for logic design was in the arithmetic unit. For example, operations such as multiplication and division must be performed as a sequence of smaller steps; this can be done in a number of ways which vary widely in speed of operation and amount of equipment. On a smaller scale, addition could be a very fast operation if time did not have to be allowed for the possibility of a carry along many digit positions; for example, to add 1 to 99999 requires five carry operations which are necessarily sequential, whereas adding 33333 to 44444 requires five operations which may be done at once. Techniques have been developed both for speeding up the carry process and for avoiding it wherever possible.

An interesting recent development in the general organisation of computer systems is introduction of time-sharing techniques, which are a feature of many current systems.

Most of the early computers were essentially sequential; one instruction had to be completed before the next could be started. This was rather uneconomic, since the parts of a computer vary in speed of operation, and the faster units spent much of their time idly waiting for the slower ones to complete an operation. Even at this stage, there was some provision for concurrent operation; most computers could carry out a sequence of internal operations between the input or output of successive words or characters, and the N.P.L. Pilot A.C.E. could in favourable circumstances have four different operations of varying speeds in train at the same time. However, there has recently been great development in this type of operation.

A simple example of concurrent operation is the autonomous operation of peripheral transfers. Suppose, for example, that our computer has a word-length of 48 binary digits and that it takes 10 microseconds to transfer a word in or out of the high-speed store; the magnetic tape units write or read six binary digits across the tape at a rate of 50,000 of these "6-bit characters" per second. Each character would thus take 20 microseconds to be read or written and

a complete word, being equivalent to eight characters, would take 160 microseconds. If a long block of data were being transferred from tape to the high-speed store, the central computer would be concerned in the operation only for 10 microseconds in every 160 microseconds. The rest of the time could be spent in internal computation or in simultaneous transfers with other tape units. In most modern computers, a peripheral transfer is specified by stating the unit concerned, the particular store locations concerned in the transfer and the number of words to be transferred; the transfer then proceeds autonomously until it has been completed, and any other sequence of internal operations or peripheral transfers may be carried out while it is proceeding. Like most modern inventions, this has its dangers; the "sequence of internal operations" may try to operate on data that has not yet been completely received. Most systems include safeguards against the types of mishap which have so far been appreciated.

A further step in concurrent operation is the facility for sharing the time of the computer among several completely independent programs. This implies some automatic procedure for determining which of these programs, other things being equal, will be executed at a given moment. The programs are usually each allocated a priority number, the highest priority program being obeyed until it is held up by, say, a peripheral transfer. Control then switches automatically to the second priority program, which is obeyed until either it is held up in its turn or the higher priority program is ready to proceed. The organisation of these interruptions may be quite complex and so may the allocation of storage and peripheral units among the various programs when they are first fed into the computer. Most systems have some sort of Supervisory Routine, a program which handles these questions of relative priority, issues instructions to the operators, gives suitable indication of various types of failure and generally tends to supersede some of the functions currently performed by human supervision.

These and other forms of concurrent operation offer interesting prospects for the operation of computers of the future. A number of data-processing procedures, requiring much peripheral operation but little computation, may proceed concurrently with each other and with a base-load job which is mainly computational; a small job, requiring very little computer time, may be performed in passing with a barely perceptible interruption of other operations.

Another interesting development in logical organisation is the variation in word-length. Most computers have a fixed word-length and are designed to operate on words of this length as rapidly and economically as possible. However, the data in data-processing applications does not fall readily into fixed-length words. Names and addresses, the number of endorsements on an insurance policy, the history of a charge-account customer involve a capriciously variable number of items and letter or digits. In order to meet this type of requirement, systems have been designed which have no fixed word-length, but operate on strings of smaller units.

A typical unit is an "alphanumeric character", represented in the system by six binary digits; the 64 alternatives which this provides allow for all the English letters and decimal digits, with room for some punctuation marks and control symbols.

These systems have set out to meet the requirements of data-processing applications involving large files of very variable format and a limited amount of computation. Their computational speed is limited, however, by the fact that each character must be dealt with separately.

Apart from these major developments in logical structure, there are a number of interesting developments in instruction format and storage organisation which have contributed considerably to overall performance, but these will not be considered in detail.

Fig. 5. Package construction is now used in almost all computers. The wiring is printed on one side of the board, the transistors and other components are mounted on the other. In the example, there are two stages of packaging, but this not always so.

programming

Before a job can be run on a computer, it must first be expressed as a program of basic machine instructions; each of these instructions specifies one of the simple unit operations that the computer is built to perform. A large program may have several thousands of instructions.

The programs for the early computers were written by highly skilled and able people, often in the course of earning their Ph.D. Today, programs are written at computer centres by girls straight from school with mathematics at A level, and in laboratories by engineers and physicists with no particular training in computer work. This might be taken as a sign of declining standards in the modern world, but the true moral is probably rather different.

Programming a computer calls for a good deal of ingenuity and also for a good deal of donkey work. The problem is to separate the various levels of skill and effort so that each may be performed as economically as possible.

This has led to interesting developments in the organisation of programming staff, and, more significantly, to the realisation that we have available a device designed for performing clerical donkey work with any amount of prefabricated ingenuity that we can be bothered to build in. This is the computer itself.

A great deal of effort has been devoted to making computers help in writing their own programs. Mathematical calculations may now be specified in a language far removed from a computer instruction code, and related much more closely to the language in which the problems would naturally be described by the mathematician, physicist or engineer. The translation from this language into a computer program is done by the computer itself; the process of translation has involved some of the largest and most sophisticated programs yet written, but this need not trouble the potential user.

These automatic programming systems have tended to be related to particular computers; they have varied widely in the extent to which they have moved away from the basic computer code towards a language well adapted to the user. More recently, there has been a move towards national and international co-operation; an International Algorithmic Language for expressing mathematical procedures has been designed by a committee from Europe, America and more recently, Britain. It is true that the resulting system, called ALGOL, has some shortcomings, but it is coming to be widely accepted and future computers are likely to offer an ALGOL translator as one of their attractions.

A similar system for programming commercial and industrial data-processing procedures would clearly be a great benefit, but a number of extra difficulties have been encountered. The first of these is that even an accounting procedure must be specified completely and unambiguously in an accepted language before it can be executed automatically; the people currently concerned with such procedures are naturally trained to specify systems related to the requirements of a local situation in terms which can be interpreted by an intelligent clerk. A second is that an automatically produced program is usually slower in operation than the theoretically best program which could be written by a human programmer; where the program is to be run on a routine basis in a system conditioned to cost accountancy, this is a significant consideration. A third consideration is that writing the computer program is usually only a small part of the work of planning and preparing the installation of a new system; this decreases the value of performing this part automatically.

This is a problem which still remains to be satisfactorily solved, though attempts have been made to impose a solution in the interest of uniformity. However, a number of satisfactory schemes have been produced to meet limited local requirements.

Since this Paper was first prepared, a system called COBOL (Common Business Oriented Language), agreed by an American committee of manufacturers and users under Government pressure, has been gaining ground. The subject is still controversial, however, and the author can make no particular claim to impartiality.

In spite of the achievements of automatic programming, programming remains, in many cases, one of the bottlenecks of automatic computation. In planning a new data-processing installation, the time for systems analysis and programming is often underestimated; in scientific and engineering problems, the time to prepare a program is often absurdly long compared with the eventual running time of the problem on the computer.

applications

Computers started in universities and Government research departments in an atmosphere of scientific and mathematical research. Early applications naturally followed; the largest known prime was greatly increased, and π was calculated to many many additional places. Applications soon followed in nuclear physics and in the analysis of molecular structures.

As the first computers came into operation, the aircraft industry had considerable requirements for numerical analysis, particularly in relation to the flutter phenomenon, but also in the analysis of fuselage stresses, control characteristics and engine performance. The nuclear power and petroleum industries also developed an insatiable appetite for computation, and there are now very few fields of engineering design which do not make some use of automatic computers.

Apart from the direct design calculations, there are performance calculations in which some equipment such as a diesel electric locomotive is taken in computational analogue through the series of circumstances it would have to meet in practice if it were ever built; as a result, it is often not built at all, or only built after substantial design modification. This is one example of economic advantages coming from a computer which are quite out of proportion to the cost of running it.

Another field of application is in operational research. The mathematical planning of management

activities has greatly expanded in techniques and application since computers were available to carry the theories into practice. For example, the operation of a complete steelworks might be simulated for varying arrangements of equipment and varying states of raw material supplies and demands for finished products; this would give the management very valuable data for planning. The stimulation which computers have given to operational research techniques might prove to be one of their most valuable contributions so far.

The possibilities of computers for commercial data-processing came to be appreciated fairly slowly, though there were notable exceptions. However, it has now become the major application.

Electronic data-processing has tended to be taken up much more readily in the United States than in Britain. Several American insurance companies, for example, do all their major policy file processing electronically, while British companies have only recently begun to place orders for large data-processing systems. The banks are in a similar position, though they have been rather later in development.

Industry offers many opportunities for electronic data-processing. The early applications tended to be confined to one area of work, such as payroll or stock control or invoicing. More recently, the trend has been towards integrated processing for the whole production process. The same system might handle, for example, processing of customers' orders, production planning, stores control, machine shop loading, costing, payroll, sales forecasting, billing, invoicing and statistical analysis for management. Automatically produced documents would include instructions to bankers for staff pay, payslips, orders to suppliers, work tickets and cash breakdowns into the various coins required for paying out.

These jobs would be done in a series of runs on the computer rather than all at once. However, these runs would be linked together by the fact that each used a common set of main files, usually stored on magnetic tape, and that in many cases the input data for one run would be the output data of another.

Computers have also been used in direct control of machine tools and to help in the operation of continuous process plant. This offers interesting prospects of linking the direct control of the manufacturing process to the integrated data-processing system.

A number of research groups all over the world have been looking into the possibilities of automatic language translation. The main object is the translation of the growing mass of technical Papers, particularly between Russian and English. A number of substantial difficulties spring to mind, but progress seems to be very encouraging. Translations sufficiently good to make the meaning clear are already being obtained and it is likely that computers will be producing completely successful translations in the next year or two, if they have not already done so.

Computers are also being used for information retrieval, that is, the extraction of relevant material from an archive or library in response to a given enquiry. Related applications are in searching for legal precedents and in diagnosing a disease from a stated list of a patient's symptoms.

Fig. 6. A modern small-scale computer. This one is designed by English Electric for industrial control applications.

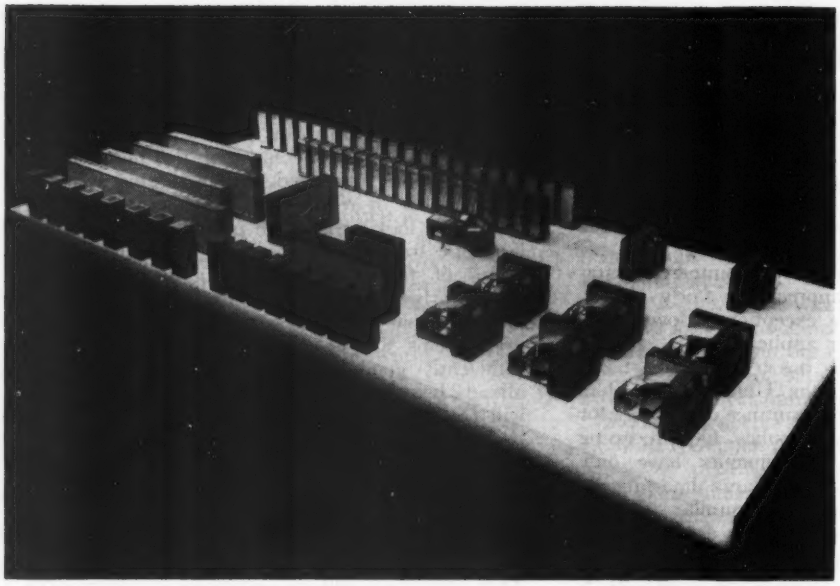


Fig. 7. An imaginative construction of a large modern data-processing system, the Gamma 60 made by Compagnie des Machines Bull. A typical medium-scale system might contain one-third to one-half of this amount of equipment.

Perhaps the most interesting techniques of computer application are those which involve learning from experience and other apparently intelligent activities. It may be difficult to see how this can be achieved with a machine which operates only according to a given fixed set of instructions. In one technique, use is made of the ability of the machine to modify its own instructions as though they were part of its data. The instructions in such a technique might be regarded as forming two separate but interrelated programs. Program A would simply perform the task in hand by a predetermined, possibly inefficient routine. Program B would test the results obtained according to some criterion of success, and would make alterations to Program A in order to improve its performance. In the crudest methods, the alterations would be random, those which produced worse performance being immediately reversed, and those which improved it retained.

Techniques of this general class have application in situations too complex to be analysed in advance and encoded in a fixed program. They are still largely experimental, and some remarkable results have been obtained. However, it is understood that there have already been some practical applications, for example in machine shop loading.

the prospect for computers

The following sketch of some of the longer-term possibilities is based on the sort of conversation one hears in places where computers are discussed. No very serious attempt has been made to distinguish between fantasy and hard prospect, since the apparently more fantastic possibilities may be the first to come and the more prosaic may never arrive at all.

While the author does not consider it possible to predict seriously beyond a few years, it should be realised that all of the forecasts made are related to developments already achieved or under development.

Computers have already entered into most fields of activity based on rational analysis and routine operation. They have caused several others to become more rational and more routine than they were before. It may seriously be expected that within the next 20 years they will begin to take over any class of work which can be sufficiently separated from its neighbours as to form a manageable job.

Technologists and middle managers may come to find their work more dependent upon and more replaced by mechanical equipment. In this development, their skills will be required by those designing the equipment and planning its application. They will also be needed in the very solid work of adapting the jobs to the machines and in the detailed planning.

In due course, computers will begin to take over higher management functions. The central computer system of a manufacturing organisation, for example, will receive continuous data on current sales, the general market position and raw material supplies. It will also have data on all activities at factories, depots and branch offices. A Board of Directors, retained for sentimental and financial reasons, will periodically make broad policy decisions; those decisions will closely follow recommendations by the computer and will in turn be fed to the computer as additional data. The computer will lay out, with superhuman intelligence, the best possible schedule of activities for following the Directors' policy. Orders for supplies will be issued at the best time to take advantage of supply conditions. The transportation of supplies will be arranged as economically as possible.

Instructions for action will be sent to all factories and depots. Raw materials will be automatically transported through a series of automatic manufacturing processes. Customers' accounts will be closely controlled, and bills, invoices, reminders, threats and

(*concluded on page* 552)

WELSH REGIONAL CONFERENCE ON "CONSERVATION OF MATERIALS"

"CROESO I GAERDYDD"!! The Conference opened rather unexpectedly with Lord Sempill's opening remarks in Welsh and he kept it up long enough to convince those from the neighbouring West of England that they really had crossed the border. Luckily, Dr. Thomas, a friend of Lord Sempill, gave a verbatim translation and the Conference continued in English.

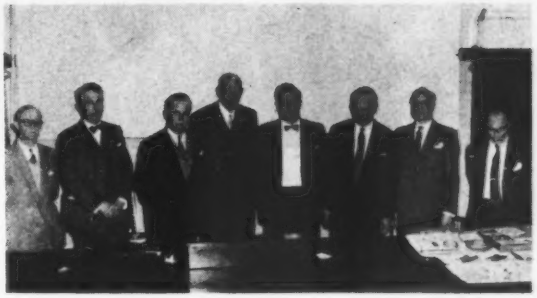
The Conference, which was organised by the Wales Region of The Institution of Production Engineers, was held at the South Wales Institute of Engineers in Cardiff on 5th May last, and was attended by 90 members and guests, who all agreed that it was a day well spent.

The first Paper, presented by Dr. C. Wilson (High Duty Alloys Ltd.), considered the savings of metals to be made in the foundry. The author discussed the aspect of increased strength, better design and the elimination of wasteful headers and gates. His main topic was on the new up-casting method whereby the pot itself acted as the feeding head. He was closely questioned and was able to satisfy his questioners.

After the coffee break, held in the Refectory of the Institute, the second Paper, on "Flame Spraying", was presented by Mr. A. Turner (Metallisation Ltd.). He gave a very wide and detailed picture of recent developments in this field. Most of those present were surprised to learn how this process had developed and it became obvious that considerable savings could be made of precious alloying elements. Questions on this Paper were numerous and at one time the writer counted nine hands raised at the same time.

Luncheon was taken at the Park Hotel, adjacent to the Institute. Apart from Grace there were no speeches from the "top table" and everyone concentrated on both meal and new-found friends. The organisers had favoured small oval tables seating eight; a small point but one of which many others could take note, as it undoubtedly contributed to the friendly atmosphere.

Mr. Basil Dyson (formerly of Hoover Ltd.) gave the last Paper: "Efficient Utilisation of Materials — An Answer to the Export Challenge". By means of numerous examples Mr. Dyson urged simplicity. Holding up in one hand a blanked strip and piercing and in the other a narrow ring-shaped component he declared: "The price of this ring is shown in my other hand and it is holding twenty times the weight of this one. Ten parts, ten drawings, ten chasers, ten forms, ten bins in the stores — two parts, two drawings, two chasers, two bins in the stores." Point after point was made by simple language and simple components.



This group, photographed during the Welsh Regional Conference, includes (left to right) **Mr. C. L. Clarke; Mr. G. R. Faulks; Mr. W. H. Bowman, Wales Regional Chairman; Mr. R. H. Thomas; Mr. T. G. Whittam; Lord Sempill, Past President of the Institution; Mr. Basil Dyson; and Dr C. Wilson.**

The Welsh love oratory and Mr. Dyson gave us all we wanted. The writer felt inspired as Mr. Dyson's *hwyl* and argument were developed. A local Managing Director declared that on the next day he would have every department giving him material utilisation figures by 11 a.m.! The audience, catching the fervour of the speaker, piled on question after question. Mr. Dyson told me that although he had lectured all over the world he had never had such a responsive audience. I said that we were a voluble nation but on reflection I think we are an emotional people who had quickly caught the fire of the speaker and had responded to it.

A quarter-of-an-hour later, when Lord Sempill closed the meeting, he insisted that we all sing the Welsh National Anthem — "Mae'n Hen Wlad fy'n Hadau" — and very well it sounded.

C. LL. GRIFFITHS

NORTH-WEST REGIONAL DINNER

The North Western Region held its Annual Dinner at the Midland Hotel, Manchester, on 5th May last. The function was as usual thoroughly enjoyed by those who attended. The toast of the guests was proposed by Mr. H. Mason, Regional Chairman, and the response was made by the Rt. Worshipful the Lord Mayor of Manchester. Dr. C. Whitworth, Principal of the Royal Technical College, Salford, proposed the toast of the Institution, to which Mr. G. Ronald Pryor, President of the Institution, responded.

Obituary

JAMES H. BINGHAM, M.I.Mech.E., M.I.Chem.E., M.I.Prod.E., M.Inst.Gas.E., M.Inst.F., F.I.I.A.; Chevalier de l'Ordre de la Couronne (Belgium).

It is with profound regret that the Institution records the death of Mr. James Bingham, one of its founder members, at the age of 69.

Mr. Bingham, who was an industrial and engineering consultant, had an outstanding record of service to the Institution. He was a past Chairman of Council and a past President of the Nottingham Section, and contributed unceasingly to the development and progress of the Institution, both as an individual and as a member of various committees. The following appreciation has been contributed by Mr. E. C. Gordon England, M.I.Prod.E. :

> " During the closing years of his life James Bingham became the victim of increasing ill-health. His death on 11th June, 1961, closes the earthly chapter of yet another of those great individualists who have contributed so greatly to ensuring, by their generous gifts of thought, energy and time, the purposeful and vigorous growth of the Institution.
>
> " He never suffered gladly departures from the clear-cut values which constituted the basis of his philosophy. He was most intolerant of individuals whom he deemed as typical of those who make expediency their creed in what he held was this anaemic age. His highly developed and colourful mordant humour invariably exasperated his opponents or endeared him the more to those who fell under his spell of deep sincerity, courage and tenacity of purpose in attempting to achieve what he held dear. One could not be indifferent to James Bingham.
>
> " His versatility of interests was remarkable. Perhaps few of his many friends were aware of his deep devotion to art. He was deeply learned in and a connoisseur of the art of international painters, famous and not-so-famous. His flair for discovering and recognising a masterpiece in the most unlikely places, and which had been rejected by professional experts, resulted in his generous gift to the Nottingham Municipal Gallery of his valuable collection.
>
> " No one was ever dull in his company, for right or wrong, in the views he expressed, he never failed to challenge one's mind to think deeply. Those who worked with James Bingham over the great many years he devoted to making his contribution to the nurturing and development of the Institution owe so much to this controversial individualist."

NOAH ROBINSON, M.I.Prod.E.

The death of Mr. Noah Robinson, a Member of the Wolverhampton Section, at the early age of 53, is recorded with deep regret. He had been ill for about six months.

Mr. Robinson, who was Joint Managing Director of Willenhall Motor Radiator Co. Ltd., Willenhall, would this year have completed 40 years with the Company. He joined the firm on leaving school and became its Joint Managing Director in 1958.

He was also a Director of Line Transport Ltd., Bilston; and of D. K. R. Scooters Ltd., Pendeford.

news of members

Mr. R. A. Courtman, Member, Senior Executive at Armstrong Whitworth Aircraft Ltd., Coventry, has been appointed Production Manager of Hawker Siddeley Aviation Ltd. He will be based at Hawker Siddeley's Headquarters at Kingston-upon-Thames.

Major H. V. Fisher, Member, is now in Germany on the staff of H.Q., R.E.M.E. Inspectorate BAOR, B.F.P.O. 34.

Mr. Z. Funt, Member, is now Vice-Principal of Gateshead Technical College, Gateshead.

Mr. E. W. Hancock, O.B.E., Honorary Member, has been elected National President of The Institute of Sheet Metal Engineering.

Mr. A. C. C. Moore, Member, having relinquished his appointment as General Manager, G.E.C. Lighting Equipment Ltd., will shortly be taking up an appointment with Messrs. R. & A. G. Crossland Ltd., Walsall, Staffs.

Mr. R. C. Shuster, Member, has been appointed Works Manager of Christy & Norris Ltd. Mr. Shuster was formerly Works Manager of E. H. Bentall & Co. Ltd.

Mr. A. Webster, Member, has relinquished his position as Production Engineer, David Brown Tractors, Meltham, and has taken up an appointment as Manager, Tool Room, Hepworth & Grandage, St. John Works, Bradford.

Mr. E. J. Bradley, Associate Member, formerly Assistant Works Manager, Foster Wheeler Ltd., has been appointed Works Manager of E. Boydell & Co. Ltd., Manchester.

Mr. J. Dunkerley, Associate Member, has been appointed Works Director of Oldfield & Schofield Co. Ltd., in addition to his duties as Works Director of Henry Broadbent Ltd.

Mr. J. W. Haig-Ferguson, M.A., Associate Member, was recently appointed Managing Director of R. & J. Beck Ltd., one of the Griffin & George Group of Companies.

Mr. T. J. Harrison, Associate Member, has now been appointed Work Study Engineer of John Thompson Ordnance Co., Wolverhampton. He was formerly Senior Production/Planning Engineer.

Mr. S. S. Jauhari, Associate Member, has taken up a new appointment as Director of Production in the Ministry of Defence, New Delhi.

Mr. E. J. Lownes, Associate Member, has relinquished his position of Midland Industrial Divisional Cutting Oil Engineer with the Mobil Oil Co. Ltd., and has now formed his own concern under the style of Oil Inventions (Midland) Ltd. Mr. Lownes is a Past Chairman of the Wolverhampton Graduate Section, and is also a member of the Institution's Materials Handling Group.

Mr. A. V. Manning, Associate Member, has taken up the appointment of Chief Production Engineer with Blackburn Aircraft Ltd., Brough, East Yorkshire.

Mr. H. E. Martin-Leake, Associate Member, has recently taken up the position of General Manager—Engineering and Production, with Kismet Ltd., Bedford.

Mr. M. P. Marsh, Associate Member, has relinquished his appointment with A.E.I. (Rugby) Ltd., and has taken up an appointment as Crane Inspector with Richard Thomas & Baldwins Ltd., at the Steelworks at Llanwen, near Newport, Monmouthshire.

Mr. R. G. Mockler, Associate Member, has moved from Montreal to take up the position of Works Manager with Judson L. Thomson Manufacturing Co., Waltham 54, Massachusetts.

Mr. G. H. Newton, Associate Member, has been appointed Works Manager, Meter, Relay and Instrument Division of the English Electric Co. Ltd., Stafford.

Mr. C. M. R. Palmer, Graduate, has recently relinquished his position with W. S. Barrow & Son Ltd., Gloucester, and has taken up an appointment in the Aircraft Instrument Division of S. Smith & Sons (England) Ltd., Cheltenham, as a Senior Planning Engineer.

Mr. J. R. Pettigrew, Associate Member, Works Manager of John Fowler & Co. (Leeds) Ltd., has been appointed a local Director of the Company.

Mr. B. L. J. Hart, Associate, has been appointed Principal of the I.C.T.'s Computer Application Training Centre at Bradenham Manor, Bucks.

Mr. B. C. Clarke, Graduate, has relinquished his position of Development Engineer with Associated Electrical Industries Ltd., and has taken up an appointment as Experimental Officer at the Metals Division of Imperial Chemical Industries Ltd.

Mr. F. Farrar, Graduate, is relinquishing his position as Production Development Engineer with The Glacier Metal Co. Ltd., Kilmarnock, and is joining Steven & Struthers Ltd., of Glasgow, as Development Engineer.

Mr. B. L. Harris, Graduate, has relinquished his position with the Boeing Airplane Co., Transport Division, Renton, Washington, and has taken up an appointment as Project Engineer with Stanley Aviation Corporation, Denver, Colorado.

Mr. K. P. Jagota, M.Sc.(B'ham.), B.E.(Hons.), Graduate, has recently returned home and has taken up an appointment with Bata Shoe Co. (Private) Ltd., Bantanagar, Parganas, W. Bengal, India.

Mr. R. Lang, Graduate, has now been appointed Chief Draughtsman of the Scottish Machine Tool Corporation Ltd., London Works, Johnstone, Renfrewshire.

Mr. P. D. Mitchell, Graduate, formerly Assistant Sales Manager of Polypenco Ltd., has been appointed Technical Sales Manager, responsible for technical sales development, new product research and general sales promotion.

Mr. G. Napier, Graduate, has relinquished his position with Rolls-Royce Ltd., and is now a Tool Engineer with Wm. Jack & Sons Ltd., Hillington, Glasgow.

Mr. R. L. Reid, Graduate, has terminated his Commission in the Royal Air Force as a Flying Officer in the Technical Branch, and has taken up an appointment as Management Trainee with Metal Containers Ltd., Ellesmere Port, Cheshire.

Mr. L. Swallow, Graduate, is now a Chief Draughtsman (Design) with the Royal Aircraft Establishment at Bedford, Naval Air Department, having been promoted from Senior Draughtsman at the War Office, R.O.F., Glascoed, near Usk, Monmouthshire.

Mr. J. Milwain — a correction

In the "News of Members" section of the July issue of *The Production Engineer,* it was incorrectly stated that Mr. J. Milwain had retired from his position as Works Manager of George Angus & Co. Ltd. (Gear Division). Mr. Milwain has, in fact, resigned from his position, but has not retired.

DIARY FOR 1961-1962

1961

AUGUST 29 - SEPTEMBER 1 — **Summer School, Cranfield** (see Journal Supplement)

OCTOBER 17 ... ... — **The 1961 Sir Alfred Herbert Paper, London.**
Speaker: **Mr. David Donne,** Charterhouse Industrial Development Co.
Subject: **"Finance in Industry"**

NOVEMBER 1 ... ... — **Annual Dinner, Dorchester Hotel, London.**
Principal Guest: **The Rt. Hon. the Viscount Chandos, P.C., D.S.O., M.C.**
(see Journal Supplement)

NOVEMBER 3 - 4 ... ... — **Materials Handling Convention, London.**
Theme: **"Profit by Handling"** (see Journal Supplement)

1962

APRIL 5 - 7 ... ... — **Aircraft Production Conference, College of Aeronautics, Cranfield.**
Theme: **"Building Aircraft for the Competitive World Market"**

Hazleton Memorial Library

ADDITIONS

The Hazleton Memorial Library is a reference and lending library freely available to members of the Institution. It is open on every weekday, excepting Saturdays and public holidays, from 10 a.m. until 5.30 p.m. Members may borrow all books and periodicals, with the exception of those which are constantly required for reference, and the current numbers of periodicals. The initial loan period is one month, and this can often be renewed upon application to the Librarian. Applications for loans, loan renewals, and for information can be made by post and telephone by members unable to visit the library; and books and periodicals can be sent to members by post, the Institution paying the cost of postage one way.

Advisory Council on Scientific Policy. **Annual Report, 1959 - 1960.** *London, H.M.S.O.,* 1960. 32 *pages.* 1s. 9d. Cmnd. 1167.

Alcan Industries Ltd. (formerly Northern Aluminium Co. Ltd.). **" Technical Notes on the Expansion of the Continuous Strip Mill at Rogerstone."** (4 Parts).

Each of these publications is printed on one side of the paper and interspersed with photographic illustrations. Part 1: Introduction — Products of the mill — General description, 12 pages. Part 2: The plant in detail, 24 pages. Part 3a: Electricity supply and distribution equipment. Part 3b: Electrical drives and controls, 13 pages. Part 4a: Buildings. Part 4b: Engineering services, 15 pages. The introduction indicates that the biggest item of new equipment being installed is the 144 in. mill, and that when the whole work is completed, the nominal output of sheet and strip will be raised from 50,000 tons a year to 70,000, plus a substantial extra capacity for hot-rolled coil and plate. Further stages of development can lead to an ultimate capacity of 175,000 tons to meet the needs of the shipbuilding, chemical engineering and railway industries.

ASLIB, London. **" Aslib Year Book, 1960 - 1961."** *London, Aslib,* 1960. 214 *pages.* 12s. 6d. to members of Aslib. 18s. to non-members.

Reference only. Not for loan.

Board of Trade. **" The Machine Tool Industry."** A Report by the Sub-Committee of the Machine Tool Advisory Council appointed to consider Professor Melman's Report to the European Productivity Agency. (Sir Steuart Mitchell, Chairman). *London, H.M.S.O.,* 1960. 36 *pages.* 2s.

British Institute of Management, London. **" National Conference, Harrogate, 1960: Sessional Meeting Papers."** *London, the Institute,* 1960. 12 *Papers in Folder.*

Contents: Roberts. Restlessness and intellectual underemployment in management trainees; Dyson. Operational changes in industry; Bevan. The accountant in management; Ormerod. Keeping in touch with change: the executive's problem; Meade. Training young workers: the practical treatment of problems of the manager's role; Mathias. Movement of industry: local and national factors; McIver. Marketing or selling?; Jacques. An objective approach to pay differentials; Brown. The restrictive trade practices act, 1956; Dichter. Incentiveness, the most important tool of management; Elliott. Planning and controlling efficient use of financial resources.

British Productivity Council, London. **" Variety Reduction."** *London, The Council,* 1960. 40 *pages.* 5s.

Presents case studies in variety reduction as put into practice by 12 manufacturing firms, small and large, each in a different industry.

British Steel Castings Research Association, Sheffield. **" Data Sheets on Dust Collectors."** (2nd edition.) *Sheffield, the Association,* 1960. 39 *pages. Diagrams.* 30s.

There are many different types of dust collectors marketed under various trade names. This series of data sheets is intended to facilitate the selection of the most suitable unit for a particular purpose. They give up-to-date details of collectors suited primarily to steel foundry applications. Thirty-two dust collectors made by 19 different organisations are described, and, as far as possible the collection efficiency, pressure drop, and water usage of each type is clearly indicated.

Climax Molybdenum Co., New York. **" Atlas: Hardenability of Carburised Steels."** 136 *pages. Charts. Tables.*

Presents the results of research by Company into the hardenability of carburised steels. The book consists principally of charts and tables.

Copeman, George. **" Executive Salaries: A New Approach."** *London, Business Publications,* 1960. 16 *pages. Tables.*

An approach to salary determination for executives, which is based on the personal abilities and progress of the employee rather than " the rate for the job ".

Hardy, H. W. **" Machine Tool Slides and Sliding Elements."** *Brighton and London, Machinery Publishing Co.,* 1960. 73 *pages. Diagrams.* 5s. 6d.

Examples of various types of sliding elements, covering a wide range of designs including simple bar guides, the more elaborate and efficient narrow guideways and ball and roller guided slides.

Contents: Preface — Simple circular, square and special section bar guides — Vee, square-edged and trapezoidal slides; strips or gibs — Narrow guideways — Ball, roller and needle roller slides; slides with hardened inserts — The lubrication and protection of slides.

Hungary. Central Statistical Office. **" Statistical Pocket Book of Hungary, 1959."** *Budapest, Publishing House for Economics and Law,* 1960. 235 *pages. Diagrams.*

Institute of Cost and Works Accountants, The, London. **" List of Members 1960."** *London, the Institute,* 1960. 598 *pages.*

Reference only. Not for loan.

Institution of Mechanical Engineers, The, London. **"Proceedings of the International Conference on Gearing, London, 1958."** *London, the Institution,* 1958. 533 *pages. Illustrations. Diagrams.*

Thirty-nine Papers were presented by authors from the United Kingdom, U.S.A. and Europe (including the U.S.S.R.). The Papers were divided into the following sections: Gear tooth loading; Tooth forms, stresses and failures; Lubrication; Production of large gearing; Production of medium gearing; Measurement; Applications. Discussions, communications and authors' replies are given.

Letsky, B. M. **"A Practical Manual of Industrial Finishes (on Wood, Metal and other Surfaces)."** *London, Chapman and Hall,* 1960, 251*pages. Diagrams. Plates.* 35s.

This is a compact reference work divided into two parts, the first dealing with wood finishes and the second with metal and other surface finishes. The introduction contains a short account of the long history of protective and decorative coating. Some chapters end with schemes of experimental work and testing methods on finishes. The layout is clear, and points numbered for characteristics of special finishes. Examples of plant layout used in the finishing processes are given.

Lincoln Electric Co., Cleveland, Ohio. **"New Lessons in Arc Welding."** (2nd edition.) *Cleveland, the Company,* 1957. *Various paging. Illustrations. Diagrams.* 14s. 6d.

This text is an enlargement of the lessons used in the Lincoln Arc Welding School. Part 1 contains basic information; Part 2, information on operating procedures for machines manufactured by the Lincoln Co.; and Part 3 gives supplementary data for minimising welding costs. The text is divided into "lessons" with practical instructions and problems to which answers are given at the end of the book.

Marsh, John. **"Partners in Work Relations: Human Problems in the Industry of the Commonwealth."** *London, Industrial Welfare Society,* 1960. 42 *pages.*

Contents: The impact of industrialisation on developing countries — Personnel Practice in the United Kingdom — The role of management associations in developing countries — Some reflection on the Duke of Edinburgh's Study Conference, 1956 — The road to management and worker co-operation in Indian industry.

Ministry of Aviation. **"Interim Report on the Chemical Contouring of High Tensile Alloy Steel Sheet Materials and Components: Report of Work Carried Out by Bristol Aerojets Ltd. under Ministry of Aviation Contract No. KF/2/04/CB.25(a)."** *London, the Ministry, Technical Information and Library Services,* 1960. 83 *pages. Photographs, Charts. Diagrams.*

Ministry of Aviation. **"Investigation of Machining Ultra High Tensile Steels Using CO2 as a Coolant: Report of Work Carried Out by Morfax Ltd. under Ministry of Aviation Contract No. 6/Gas/956/CB41(c)."** *London, the Ministry, Technical Information and Library Services,* 1960. 73 *pages. Charts. Diagrams.*

Ministry of Aviation. **"An Investigation into Electrode Materials for Electrospark Machining: Report of Work Carried Out by the B.S.A. Group Research Centre under Ministry of Aviation Contract No. KG/25/01/CB.13(b)."** *London, the Ministry, Technical Information and Library Services,* 1960. 18 *pages. Tables. Diagrams.*

Ministry of Aviation. **"The Manufacture and Testing of a Hydraulic Jack in Titanium Alloy and the Machining of Titanium Alloy Forgings and Extrusions: Report of work carried out by Bristol Aircraft Ltd. under Ministry of Aviation Contract No. 6/Aircraft/11629/CB.9(c)."** *London, the Ministry, Technical Information and Library Services,* 1960. 135 *pages. Photographs. Diagrams.*

Ministry of Aviation. **"The Performance of High-Speed Milling Cutters Treated by the Spark Hardening Process: Report of Work Carried Out by the Production Engineering Research Association of Great Britain under Ministry of Aviation Contract No. 6/M. Tools/13254/CB.37(b)."** *London, the Ministry, Technical Information and Library Services,* 1960. 23 *pages. Mimeo. Photographs. Graphs. Diagrams.* (S and T Memo 17/60).

Ministry of Aviation. **"Report on the Machining of Titanium Alloy (6A1.4V) Forgings: Report of Work Carried Out by the De Havilland Aircraft Co. Ltd. under Ministry of Supply Contract No. 6/Expt1/4335/CB.38(b)."** *London, the Ministry, Technical Information and Library Services,* 1960. 12 *pages. Photographs.*

Ministry of Aviation. **"Stretch Forming of Sheet Materials Using Ice as a Lubricant: Final Report of the First Stage of the Investigation. Report of Work Carried Out by A. V. Roe & Co. Ltd. under Ministry of Supply Contract No. 6/Expt/4650/CB.38(c)."** *London, the Ministry, Technical Information and Library Services,* 1960. 12 *pages. Diagrams. Graph.* (S and T Memo 18/60).

Ministry of Education. **"Better Opportunities for Technical Education."** *London, H.M.S.O.,* 1961. 23 *pages. Chart.* 1s. 3d. Cmnd. 1254.

Ministry of Education. **"Education in 1959: Being the Report of the Ministry of Education and Statistics for England and Wales."** *London, H.M.S.O.,* 1960. 253 *pages.* 14s. 6d. Cmnd. 1088.

Ministry of Labour. **"Chief Inspector of Factories: Annual Report, 1959."** *London, H.M.S.O.,* 1960. 128 *pages. Tables.* 7s. Cmnd. 1107.

Ministry of Labour and National Service. **"Central Youth Employment Executive — Professional Engineers."** *London, H.M.S.O.,* 1960. 55 *pages. Photographs.* 1s. 9d. (Choice of Careers, No. 92).

A survey directed to schoolchildren, of the work of professional engineers of various kinds; their training and prospects.

British Transport Commission. **"Project: a periodical issued by the Work Study Organisation of the British Transport Commission."** *Irregular.*

Volume 1, No. 1, January, 1961, of this new periodical, which will record progress and development of work study throughout the British Transport Commission, includes articles on operational research; work sampling; and human relations. It describes the new reservation procedure for the Continental car ferry service, and a pilot scheme for signal engineering maintenance in Scotland. The periodical is not available to the general public.

Rider, H. G. **"Workshop Engineering Practice: An Introductory Course for Engineering Students and Apprentices. Volume 2, Lathe Work."** *London, Iliffe,* 1959. 137 *pages Diagrams.*

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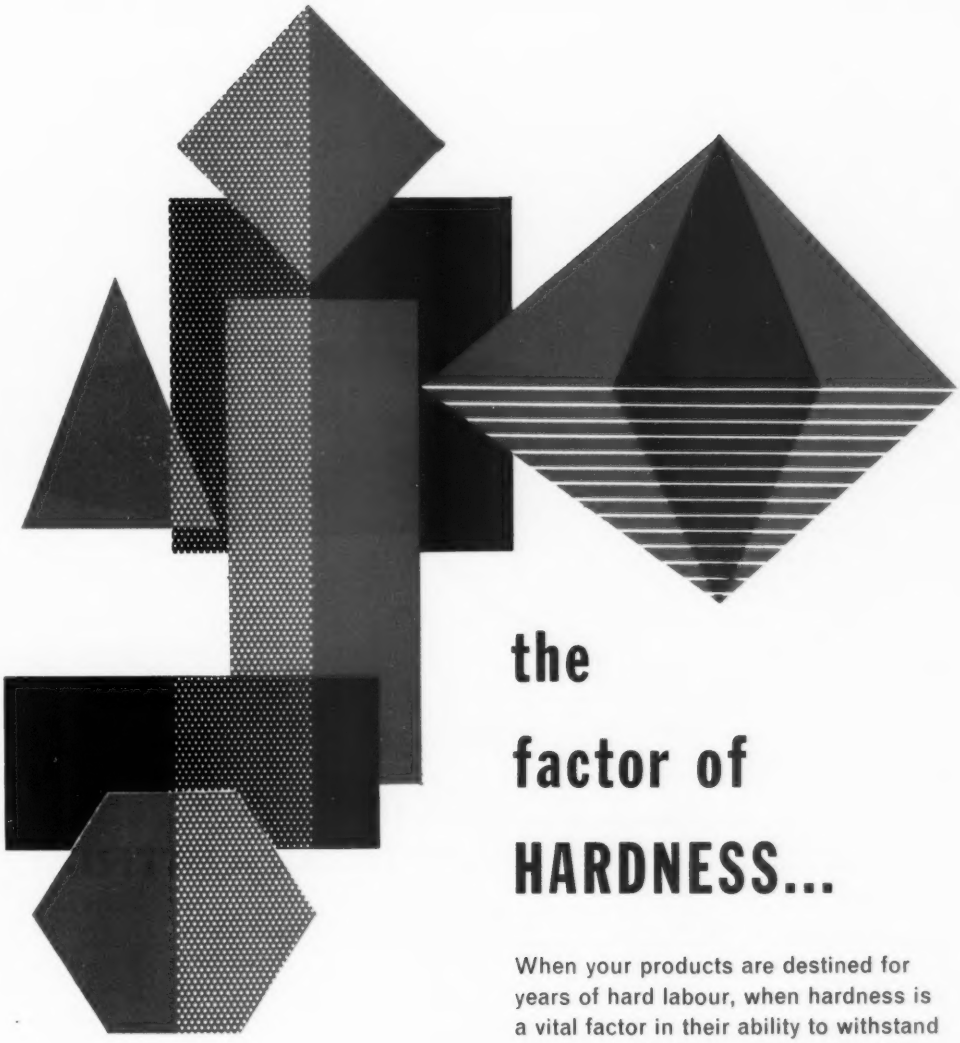

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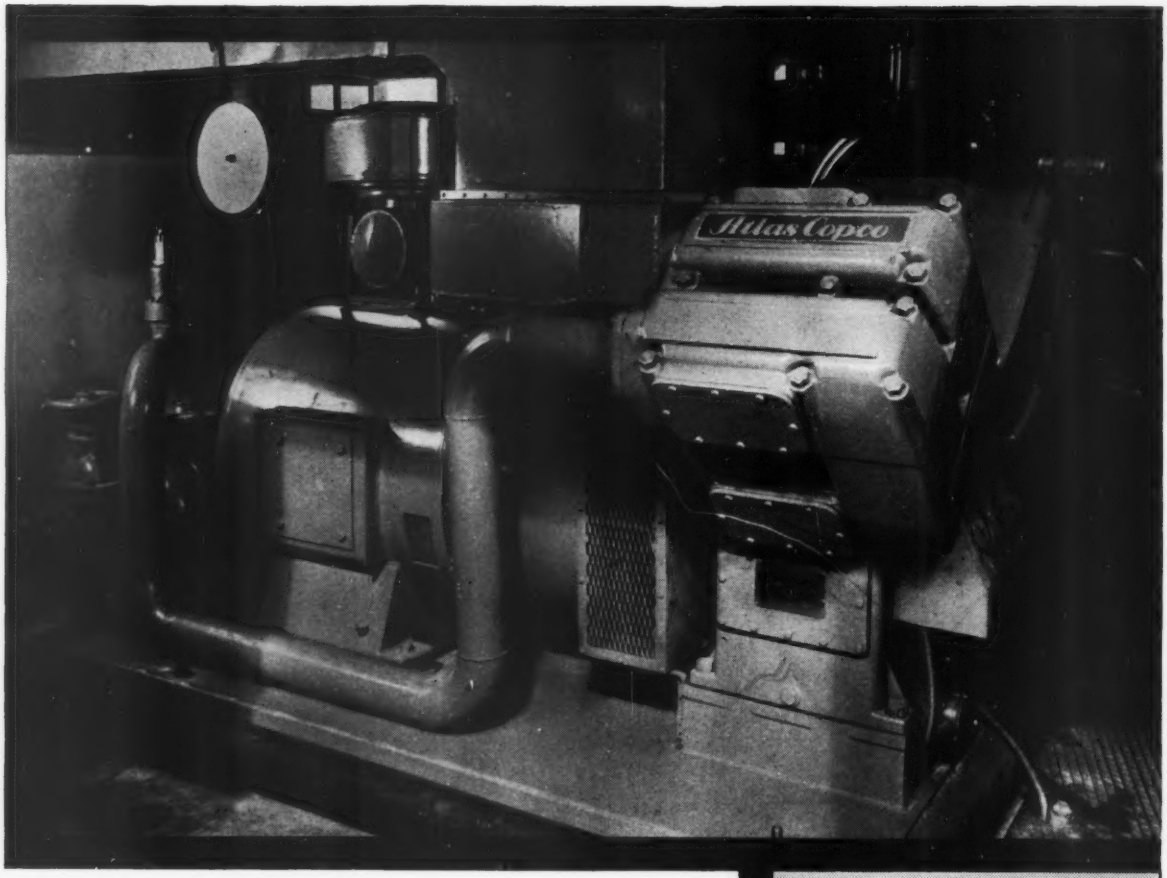

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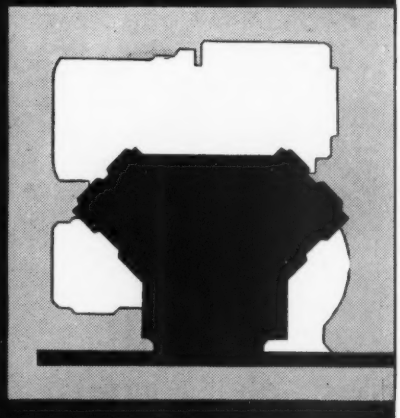

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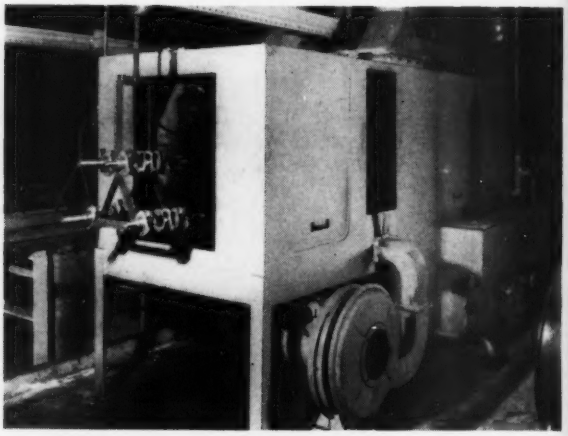

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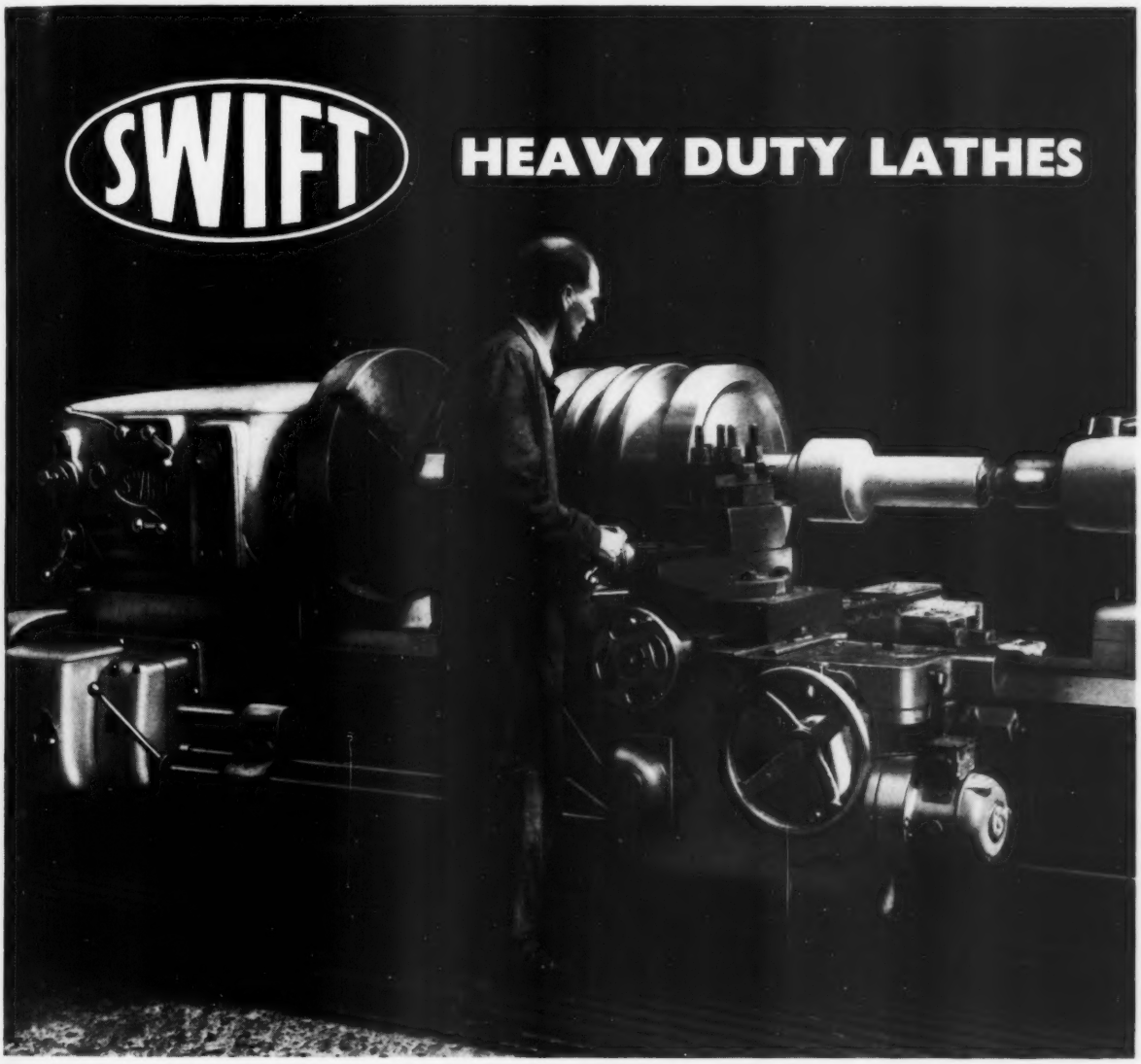

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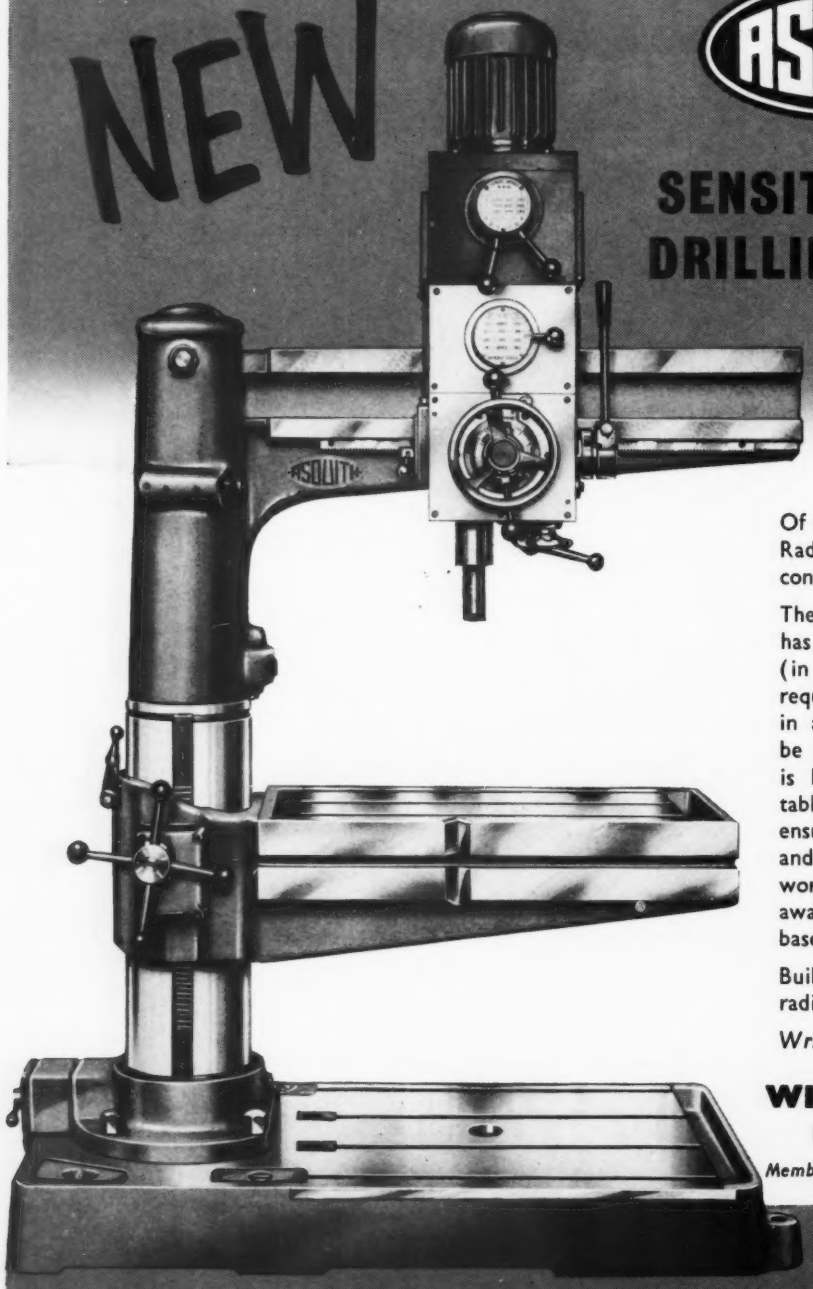

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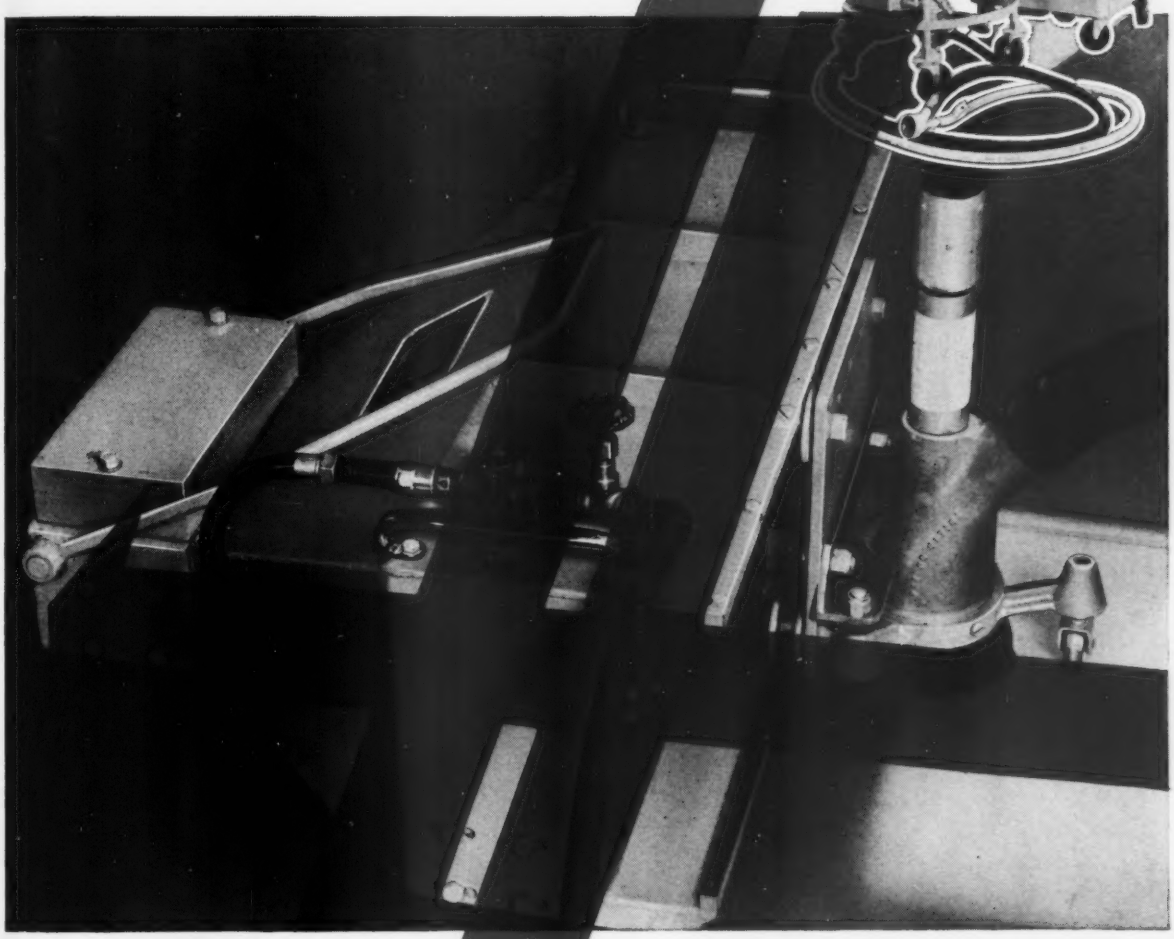
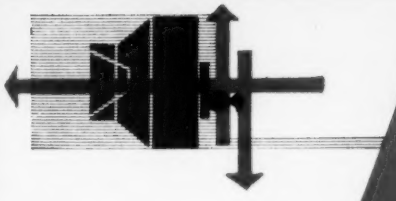
KING EDWARD HOUSE, NEW ST., BIRMINGHAM *Phone: Midland 3431. Also at LONDON Phone: Trafalgar 7224 & GLASGOW Phone: Central 0922*

A492

The CRAWLER with a turn of speed





The Vacu-Blast automatic crawler unit has been designed primarily for the removal of tenacious millscale from flat steel plate.

The Crawler may be used with equal advantage for removing heavy corrosive deposits and thick layers of pairt and other protective coatings prior to re-application on a suitably grit-blasted surface.

The Vacu-Blast 'Senior', 'Major' and 'Majorette' machines may be used with the Crawler, and we should be happy to advise upon the most suitable unit to meet your production requirements.

VACU-BLAST LIMITED

Wellcroft Road · Slough · Bucks. Telephone: SLOUGH 24507/9

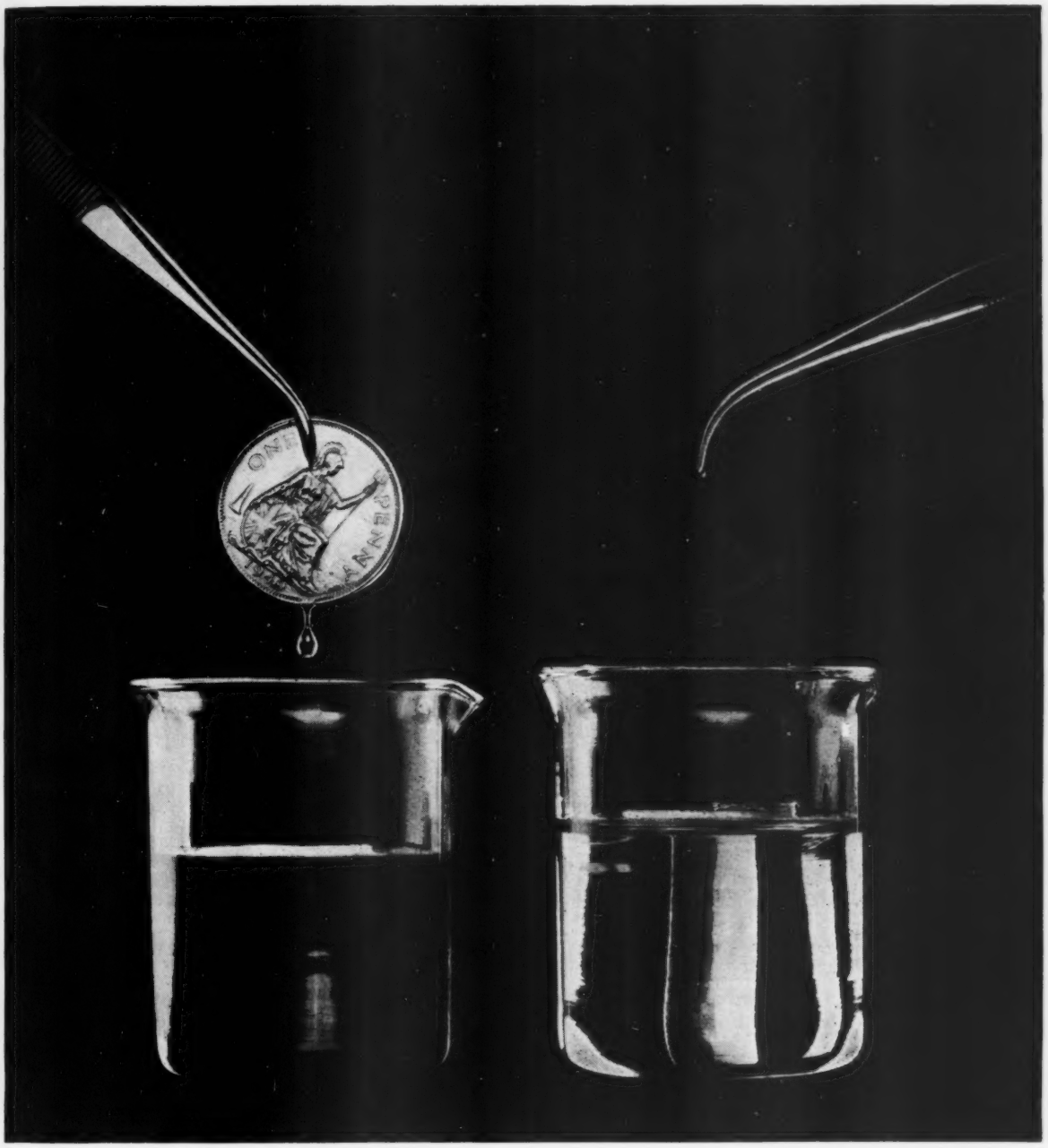
Shell achievement

One of Shell's recent achievements in Industrial Lubrication has been to reduce the risk of skin trouble for machine operators. Until the new Shell Dromus range, most modern soluble cutting oils contained phenolic compounds, which can cause skin irritation. They were used as coupling agents between the actual oil and the emulsifier. On high-speed machines, especially, the water evaporates and the emulsion concentrates. And that's when the trouble can start. Shell scientists found a better coupling agent, and made it work. And now, at no extra cost, management can reduce working risks for their staff. *Write for the book, 'Selecting Your Cutting Oils', to Shell-Mex House, London, W.C.2.*

SHELL

SHELL INDUSTRIAL OILS

Shell demonstration

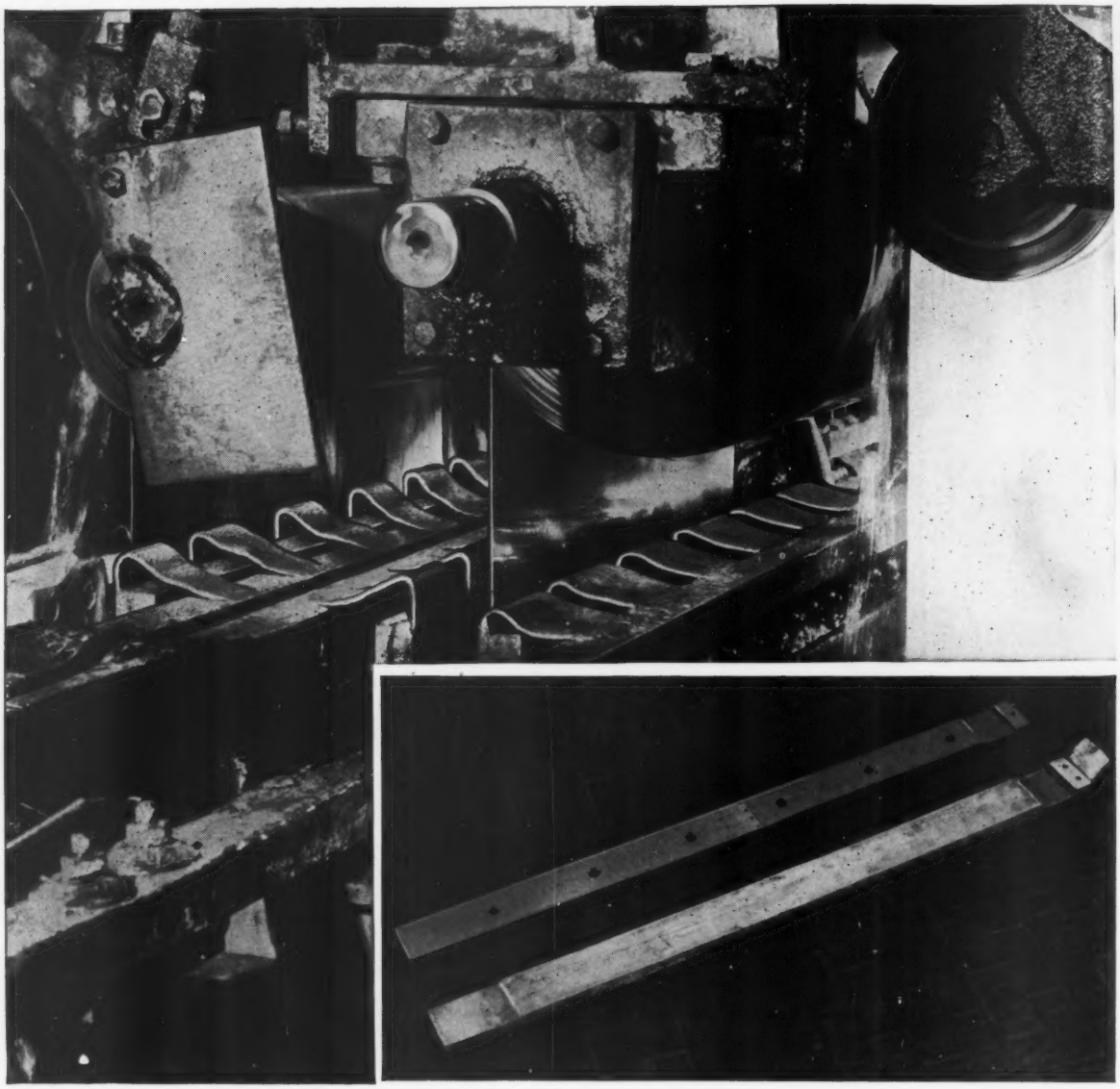


Two clean, bright pennies are placed in beakers of oil, of equal performance level, one Shell Garia Oil 21, the other a conventional cutting oil containing sulphurised additives. After three hours at room temperature one penny is still bright and stain-free, the other heavily stained with black copper sulphide. The bright penny is from the beaker containing Shell Garia Oil 21, the blackened one from that containing the conventional oil. While these were just pennies they could have been bronze bushes in your machine tools—stained in less than half a shift. Sulphur is essential in heavy-duty cutting oils. Special additives in Shell Cutting Oils protect your machine tools and yet allow the sulphur to do its job. *Write for the book "Selecting Your Cutting Oils" to Lubricants Department, Shell-Mex House, London, W.C.2.*

DROMUS . . . PELLA . . . MACRON . . . GARIA

SHELL

SHELL CUTTING OILS



Why the Steel Company of Wales relies on TUFNOL for anode cores

For more than two years the Trostre works of the Steel Company of Wales has been using lead covered "Whale" Brand Tufnol anode cores with great success in Electrolytic Pickling Tanks.

They lower the cost of the anodes by reducing the amount of lead required. This in turn saves weight and makes for easier handling. Stoppages are reduced and maintenance costs cut because the anodes are more rigid and robust, and the cores can be recovered.

This use for Tufnol in the plate industry can be extended with equal success to similar applications.

There are eleven other brands of Tufnol, available in sheets, tubes, rods, angles and channels. All brands are laminated plastics; each formulated to satisfy specific requirements. Your local Tufnol Branch Office will gladly supply you with further information.

'WHALE BRAND'

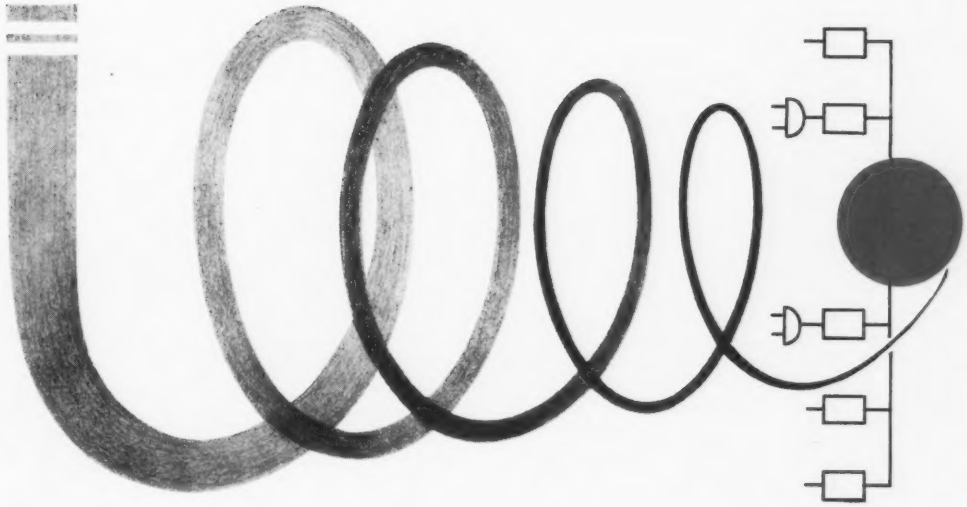
TUFNOL

(REGD. TRADE MARK)

TUFNOL LIMITED · PERRY BARR · BIRMINGHAM 22B

396

BI-Stat
SYSTEM



what is it?
BI-Stat is BHI's static, no-maintenance control system.

what does it do?
It controls any automatic sequence of motor operations, excelling at complex ones.
It does anything that any electro-mechanical relay system can do,
and does it without breakdowns—and without maintenance.
BI-Stat goes on...and on...and on.

on...and on...and on..
...because BI-Stat switching is entirely devoid of moving parts and contacts.
...because BI-Stat components are totally encapsulated.

BI-Stat suffers no burn-outs, maladjustment, wear or corrosion,
no sticking or fouling or fatigue.
BI-Stat works happily amidst dirt, oil, moisture and fumes.
BI-Stat is supplied as BHI-engineered equipment, or as components for
your own systems.

Write for Publication ZB35 and consult BHI for the BI-Stat answer to your problems. BI-Stat will solve them permanently.

BHI
Metal Industries Group

BROOKHIRST IGRANIC

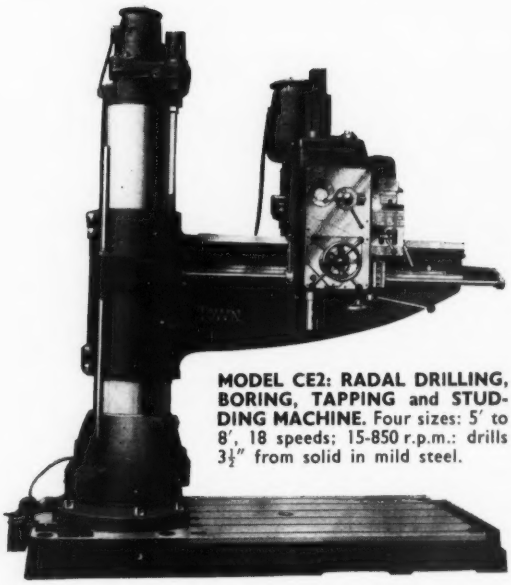
Enquiries to:
BI-STAT DIVISION · NORTHGATE WORKS · CHESTER
MAKERS OF BRITAIN'S WIDEST RANGE OF ELECTRICAL CONTROLS & ASSOCIATED EQUIPMENT

BI/58

TOWN

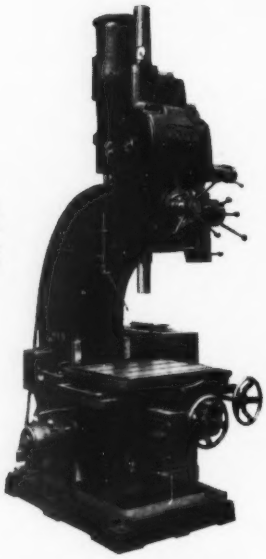
DRILLING MACHINES

Established over 50 years, the TOWN range of radial and vertical drilling machines is noted throughout the world for modern design, reliability and ease of operation.

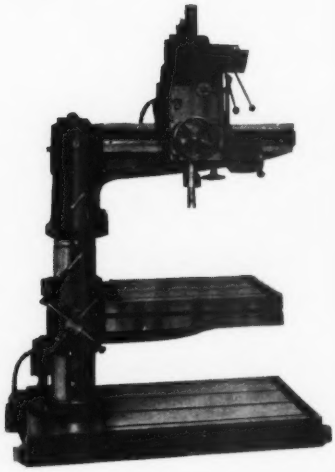


MODEL CE2: RADAL DRILLING, BORING, TAPPING and STUDDING MACHINE. Four sizes: 5′ to 8′, 18 speeds; 15-850 r.p.m.: drills 3½″ from solid in mild steel.

MODEL AE4: RADIAL DRILLING, BORING, TAPPING and STUDDING MACHINE. Seven sizes: 3′ 6″ to 8′; drills 3″ from solid in mild steel.



MODEL AE2: VERTICAL DRILLING MACHINE (Heavy duty model). Two sizes: 36″ and 42″: drills 3½″ from solid in mild steel.



MODEL AE5: RADIAL DRILLING, TAPPING and STUDDING MACHINE. 42″ drills 1¼″ from solid in mild steel or 1½″ in cast iron.

MODELS EG4 and EG8: GIRDER RADIAL DRILLING MACHINES. Each model in five sizes: 4′ to 8′, 4 speeds; 160-600 r.p.m. (EG4), 8 speeds; 20-500 r.p.m. (EG8) drills up to 2″ from solid in mild steel. Also made with single speed.

OTHER MACHINES IN THE RANGE

are detailed in a folder 'GO TO TOWN' which is available on request. Variations on the standard range can be undertaken, and examples are also illustrated in the folder.

FRED^K. TOWN & SONS LTD | **HALIFAX · ENGLAND**

ESTABLISHED · 1903 | **PHONE: HALIFAX 60373/4**

T18

work to fine limits

with Eclipse

'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd. and are obtainable from all tool distributors.

UXE2

Gosheron tapes

serving industry — everywhere

all-purpose SELF-ADHESIVE transotape

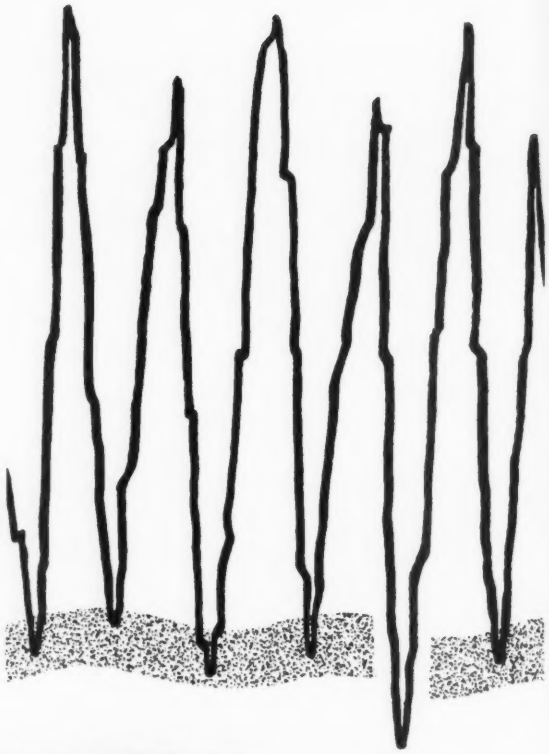
The cellulose tape of *quality*, for all sealing, protecting, securing and repairing needs.
TRANSOTAPE—in clear transparent and attractive opaque colours—a Gosheron *standard* product.

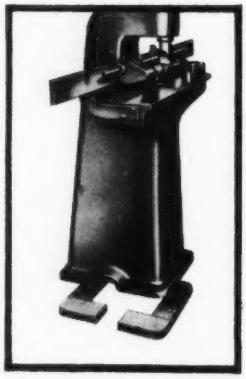
Write for "Tape Times" now — the up-to-date journal for all tape users.

John Gosheron & Co. Ltd

THE PACKAGING & INDUSTRIAL TAPE CENTRE
ALBERT EMBANKMENT · LONDON, S.E.1
RELiance 7600/9

Photo courtesy Highams Ltd.





Imagine the reduction in nervous tension amongst your employees when you reduce vertical vibration by 80%. Imagine the reduction in machine wear, too. Yet an 80% reduction is perfectly feasible for many types of machinery with the Croid-Cooper method of installation, where the machine is simply stuck down on a felt base with a holding power of 50 lbs to the square inch. May we send you details?

THE CROID COOPER METHOD OF MACHINE FIXING DAMPS VIBRATION

CROID 65
MACHINE FIXING GLUE
COOPERS FELT

COOPER & COMPANY (Birmingham) LIMITED
Head Office and Works:
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Branch Office and Works:
SEELEY'S ROAD, BIRMINGHAM 11 TELEPHONE: VIC 5417

TAKING THE BISCUIT

'Socast' steel castings are produced by the precision methods of the Shell Moulding, Osborn Shaw and Osborn CO2 Block processes. Intricate designs may be cast in stainless and other steels, to close tolerances and high quality finish. These castings drastically reduce, or even eliminate machining of many components, and in this way are lowering production costs for many users.

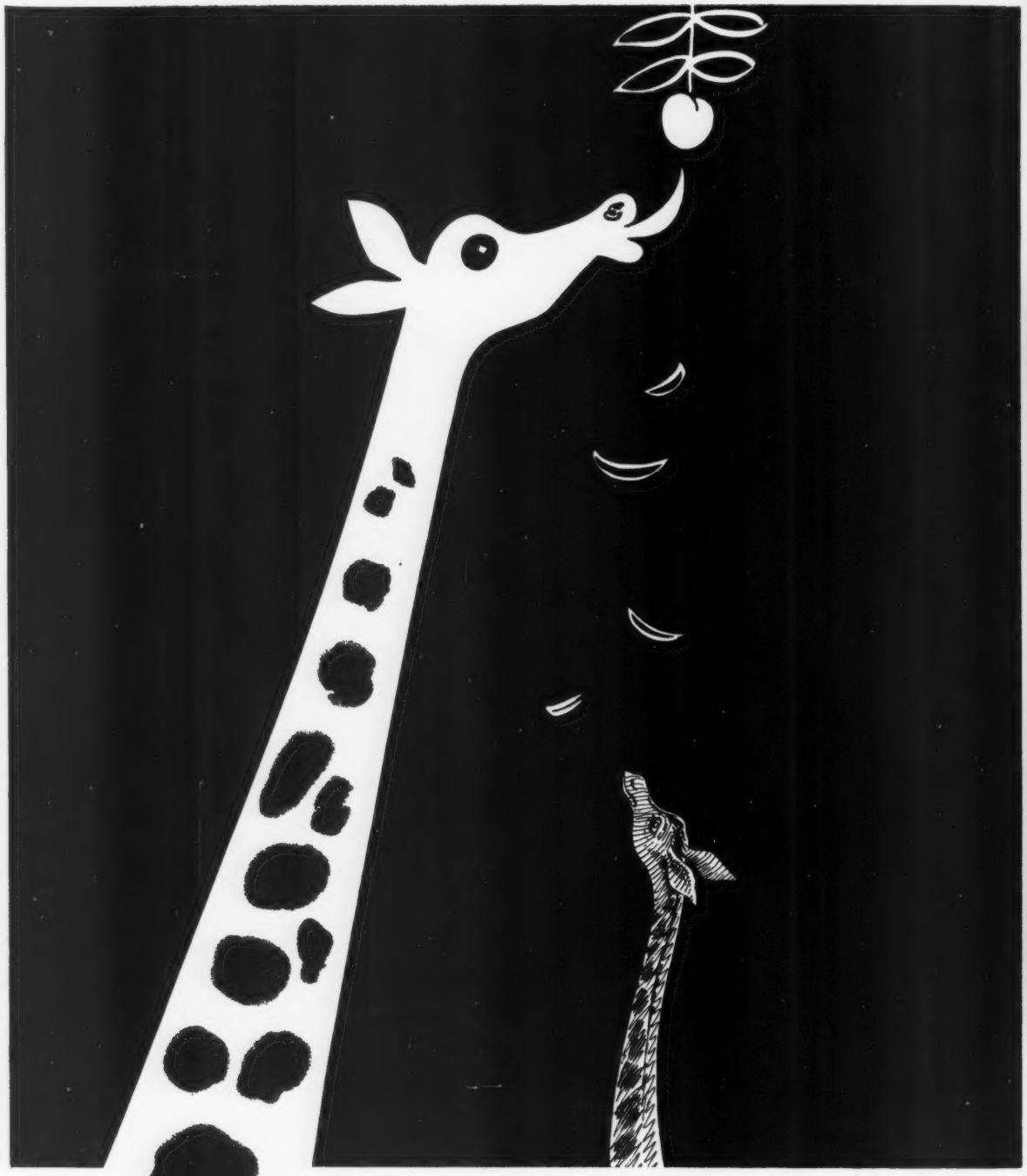
Please send for further details and fully illustrated brochure, No. 7 — 'Socast Steel Castings'.

OSBORN 'SOCAST'

STEEL CASTINGS
BY PRECISION METHODS

SAMUEL OSBORN & CO., LIMITED
CLYDE STEEL WORKS SHEFFIELD

Steelmakers · Steelfounders · Engineers' Toolmakers



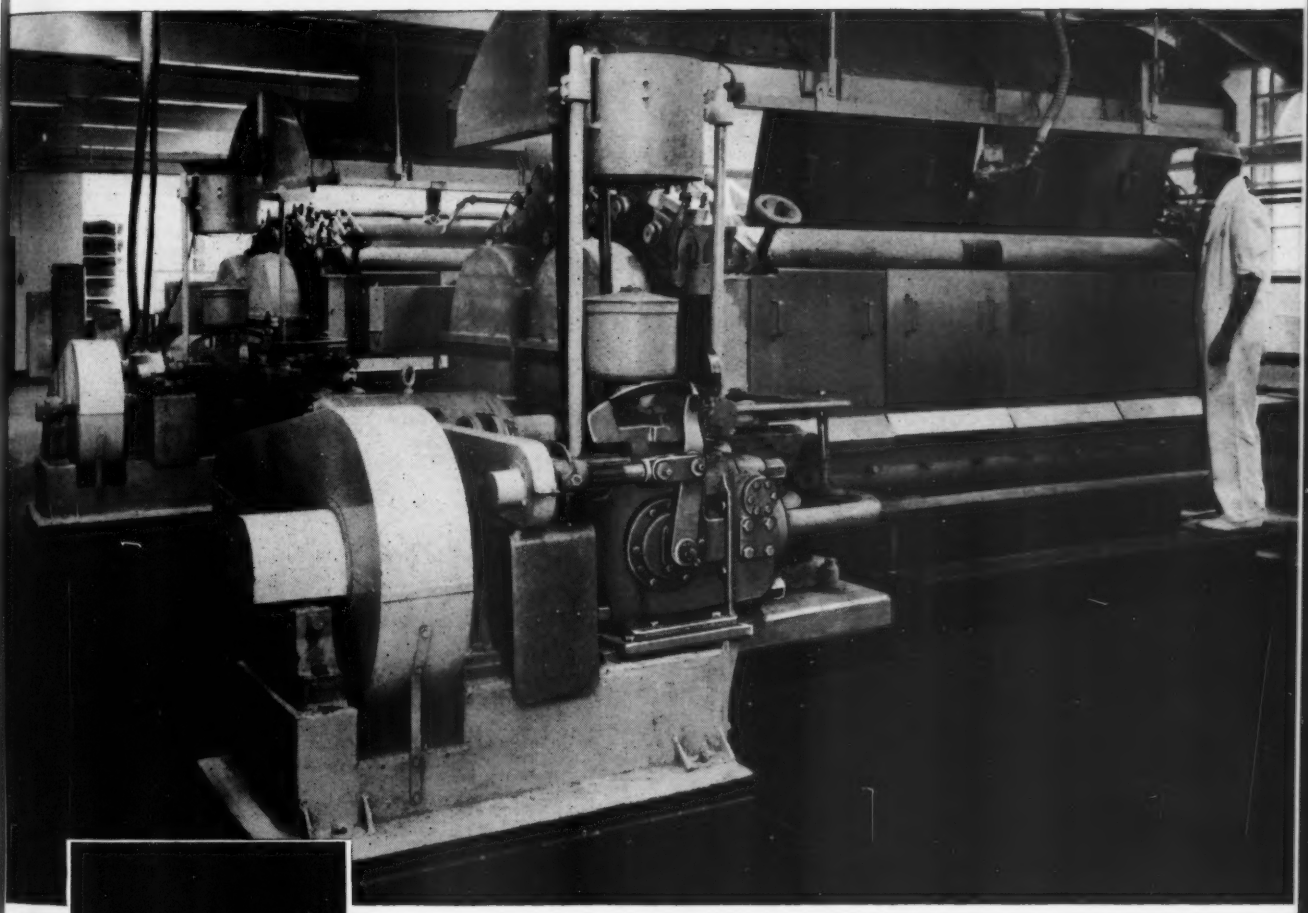
Sometimes it pays to stick your neck out

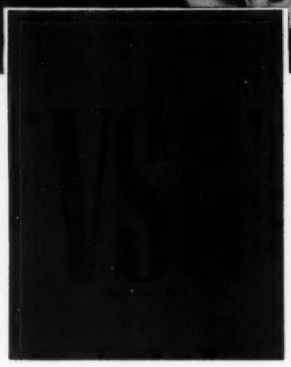
The juiciest plums are at the top of the tree: perhaps you dream of reaching for them? But that means growing. And growing costs money. Money? Why, that's just what UDT is for. If it's time you added or replaced equipment: if it's time you modernised your production: if it's time you enlarged your premises: then it's time you came to us at UDT. Maybe we can help you to those juicier plums.

UDT HELPS INDUSTRY TO HELP ITSELF

UNITED DOMINIONS TRUST (COMMERCIAL) LIMITED · 51 EASTCHEAP · LONDON EC3

HYDRAULICS serve the very young...





VSG Mark III Hydraulic Transmission Gears capable of 50 H.P. output driving Richard Simons & Sons Ltd., twin cylinder drying machines in the Farex Dept. at Glaxo Laboratories Ltd., Greenford, Middx.

INFINITELY VARIABLE HYDRAULIC TRANSMISSION GEARS

VICKERS-ARMSTRONGS (ENGINEERS) LTD

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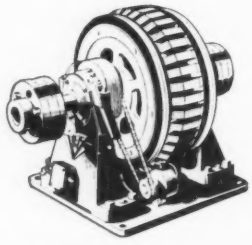
34C

The technical "know-how" of DRIVE CONTROL!

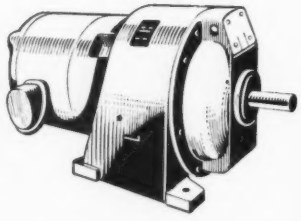
The Heenan-Dynamatic Variable-Speed Coupling is a device which is coupled to a constant speed motor in order to provide a controlled variable-speed output. One element of the Coupling runs at motor speed, the other runs at any lower speed desired, thus giving stepless speed variation. That is the beauty of fully-automatic speed variation and speed control — brought to *almost every industry* by the wide range of Heenan-Dynamatic Variable-Speed Couplings and Drives.

It is a system that has solved problems which have defied conventional solution. Throughout industry in fact, Heenan & Froude have become the authority on all aspects of speed control.

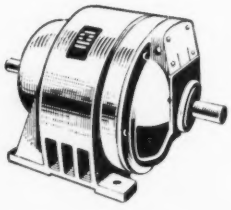
Remember – There is no Substitute for experience



DYNAMATIC



DYNASPEDE



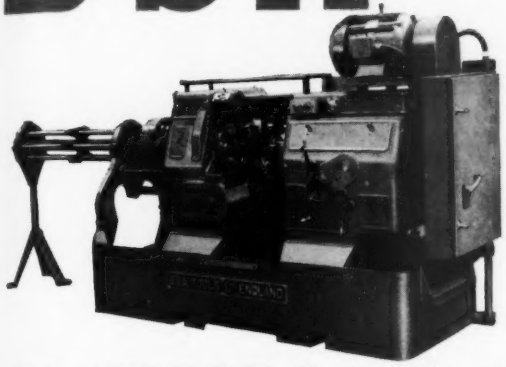
AJUSTO-SPEDE

DRIVES BY HEENAN & FROUDE

ENGINEERS, WORCESTER

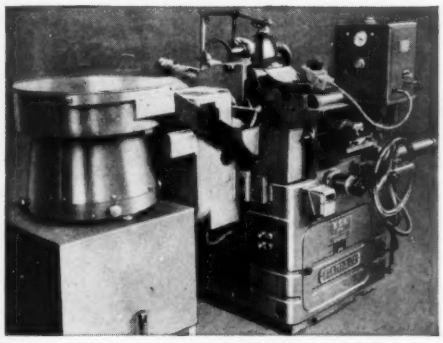
H-W.64

B·S·A production machines

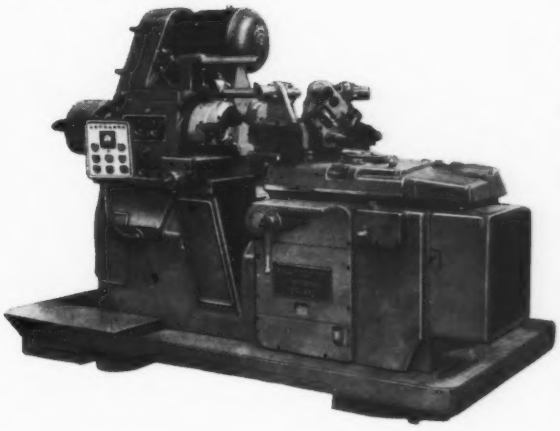


B.S.A. ACME-GRIDLEY $\frac{3}{8}$" six-spindle automatic bar machine. Designed for high spindle speeds and fast cycle times combined with accuracy and good surface finish. Machine has two position feeding and stock can be fed during index. The main toolslide is provided with end adjustment to assist setting up for components of similar design but of varying length. Collet capacity $\frac{3}{8}$" dia. Length fed and turned 4". Speeds 4,340 to 321 r.p.m. Motor 15 h.p.

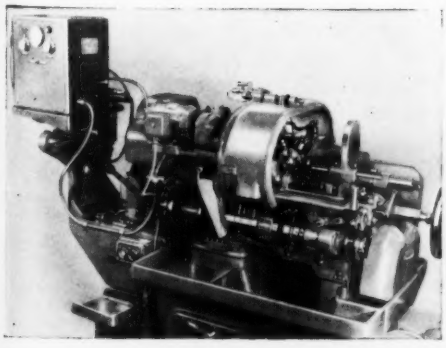
B.S.A. 5M single-spindle chucking automatic linked to a B.S.A. ACME-GRIDLEY 6" six-spindle chucking automatic. After first operation machining the component is conveyed via the overhead chute to the multi-spindle machine for completion. Chucking is electro pneumatic.



B.S.A. No. 4 centreless grinding machine with automatic sizing control and automatic infeed. In this set-up special bolts $\frac{7}{16}$" x $2\frac{7}{8}$", fed from vibratory type hopper, are ground to a tolerance of 0.0005" ; 700 per hour.



B.S.A. No. 95 All-Electric single-spindle automatic chucking machine with " DISCOTROL " programme control unit. (Complete machining programme for a component recorded on a master disc.) Immediate changeover effected by substituting a new programme disc and appropriate tooling. Re-setting of machine speeds and feeds eliminated. Highly sensitive overload device protects tooling. Five-face turret. Swing over cross slides $10\frac{3}{4}$" (maximum swing $12\frac{1}{2}$"). Stroke : of cross slides 4", of turret $5\frac{3}{4}$". Thirty spindle speeds : 40 to 834 or 60 to 1220 r.p.m.



B.S.A. No. 48 single-spindle automatic screw machine arranged for automatic inspection of 0.0150" hole through component. Obstruction to an air blast through the hole causes a back pressure to be fed to a control which stops the machine.

TRADE MARKS
B·S·A TOOLS DIVISION

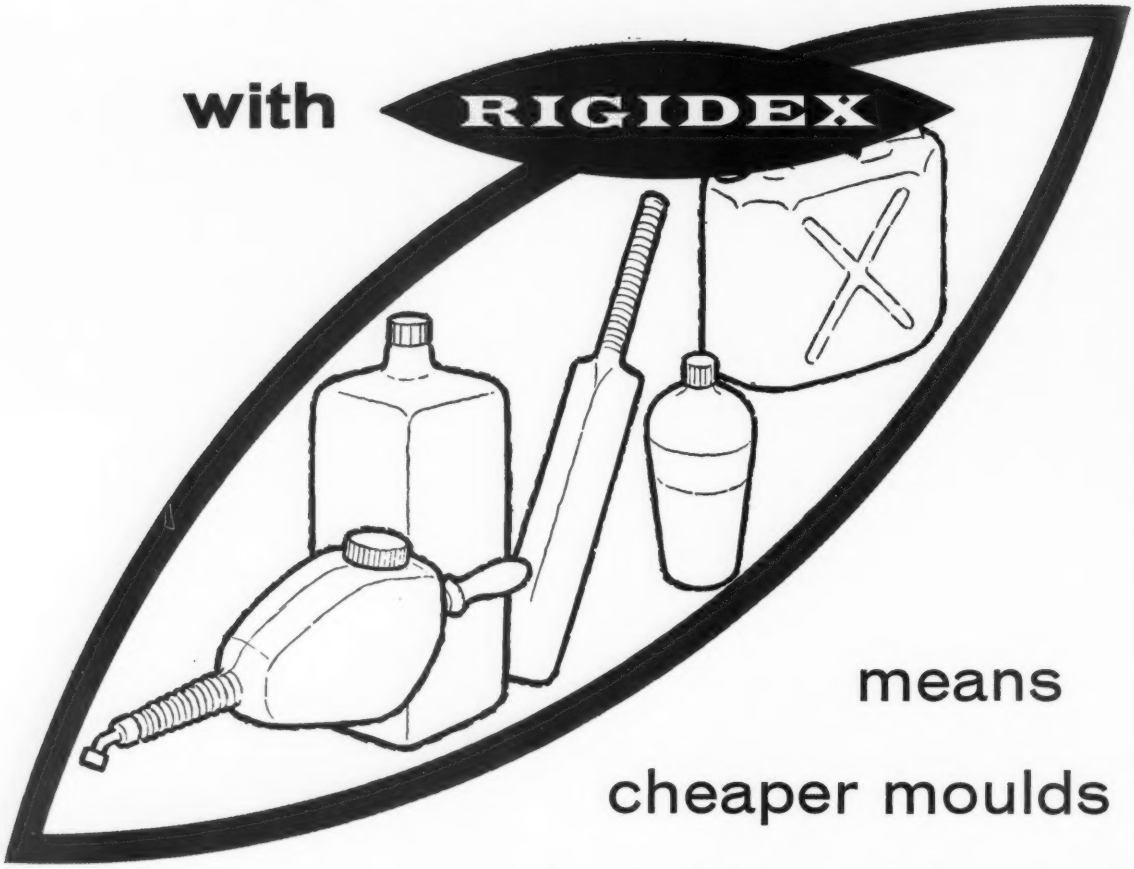
B.S.A. TOOLS LTD., BIRMINGHAM, 33 ENGLAND
CABLES : MADRICUT BIRMINGHAM TELEX 33207

Sole Agents Gt. Britain
BURTON GRIFFITHS & CO. LTD.
Mackadown Lane, Kitts Green, Birmingham
Telephone : STECHFORD 3071

493

blow-moulding

with RIGIDEX



means

cheaper moulds

no welding–no waste

Blow mould your products in Rigidex polyethylene and in one operation you give them all the features that count in today's highly competitive markets . . . dependably functional design, seam-free construction, durable colours and unrivalled resistance to abrasion, corrosion and stress cracking. All this and economical construction too! Blow-moulding with Rigidex eliminates welding, cementing and the need for hardened steel moulds. All scrap can be used. And the strength of Rigidex, even in thin sections, permits valuable savings in raw materials. If you have yet to experience the advantages of Rigidex strike the first blow now. . . .
WRITE FOR BOOKLET NO. 354 TODAY.

Rigidex is a reg'd trade mark of British Hydrocarbon Chemicals Ltd and one of the products they manufacture at Grangemouth.
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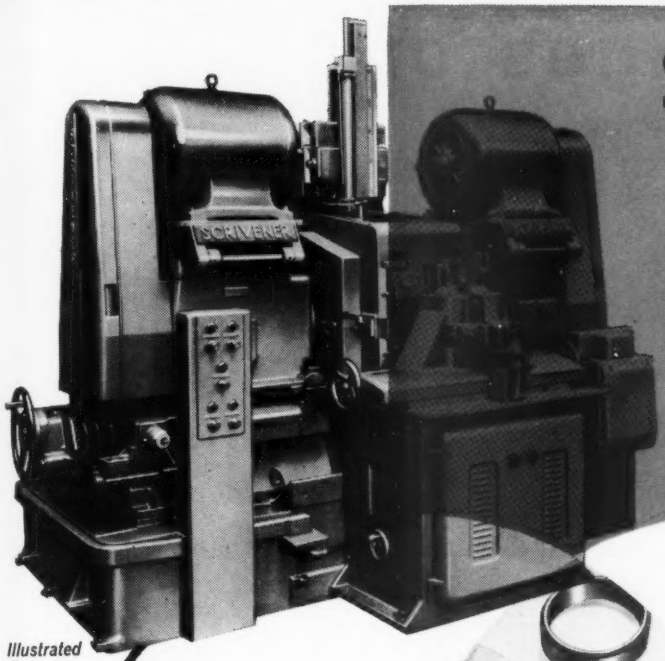
Distillers Plastics Serve Everyman

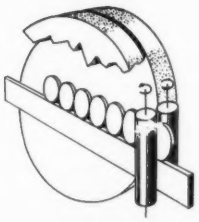
SCRIVENER

Duplex

Face Grinding Machine

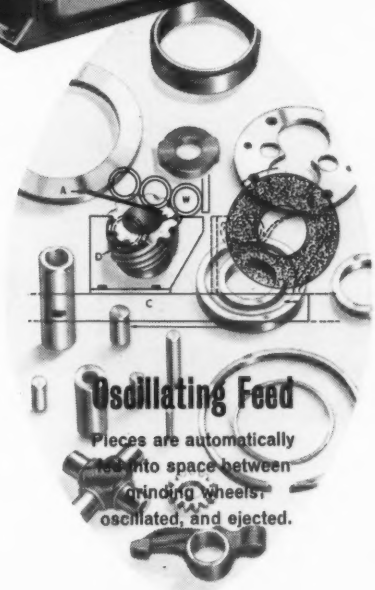


Illustrated Scrivener 24/30



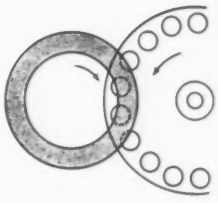
Roller Feed

Flat work-pieces capable of being rolled are best fed between vertical pressure rollers.



Oscillating Feed

Pieces are automatically fed into space between grinding wheels, oscillated, and ejected.



Rotary Feed

Irregular flat pieces which will not roll or slide can be handled by a rotary feeder.

The Scrivener 24/30 Duplex Face Grinding Machine employs the principle of mounting two large grinding wheels on horizontal spindles, with their cutting faces parallel so that workpieces passed between them have their opposite faces ground simultaneously.
This machine is designed to deal with the wide range of duplex grinding applications which exist in the engineering and other industries where components require grinding on two flat opposing surfaces to close limits of accuracy.

Typical components are:

Automobile Industry — — Piston Rings, Brake Discs, Cylinder Heads.

General Engineering — — Spacing Washers, Roller Bearing Rings, Sleeves.

Electrical Industry — — Insulators, Spacers, Condenser Parts.

Plastics Industry — Ebonite Meter Discs, Pump Discs.

Write to Wickman Ltd., for a copy of the Scrivener 24/30 Catalogue giving full details and specifications.

WICKMAN LIMITED

FACTORED MACHINE TOOL DIVISION · BANNER LANE, COVENTRY. Tel: Tile Hill 65231

566 F80

the advantages of

COLD EXTRUSION

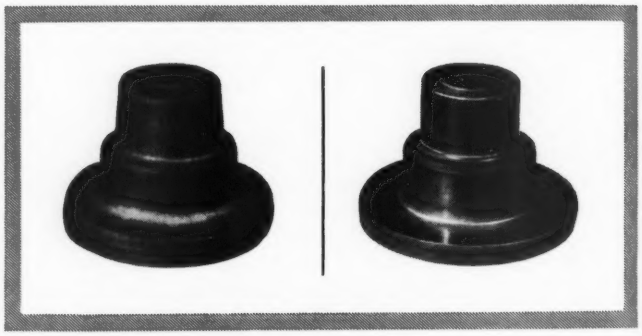
A process of controlled working which
converts a cold steel slug into a useful article.

UP TO 95% MATERIAL USAGE

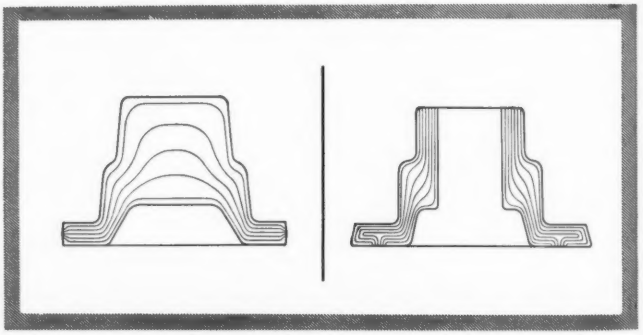
An unusually high proportion of the initial blank is usefully employed and close tolerances can be held. Economic advantage over other methods results from material savings and decreased machining costs.

The heavy cold working imparts the strength of a heat treated steel to low carbon steel whilst the excellent grain flow closely following the finished contour, and the smooth surface finish, show to marked advantage under conditions of fatigue.

Forgings and Presswork Ltd are now equipped to produce a wide range of cold extruded steel parts and would welcome the opportunity to apply their specialized knowledge to *your* products.



The Motor Car Propeller Shaft Flange shown above (left), was formerly made from Heat Treated EN8 steel. It is now produced from low carbon steel whose properties after extrusion (right) are equal to those of the EN8.



The pattern of flow lines in an extrusion (illustrated above) follows the external contour closely and is superior even to that of a forging where generous machining allowances are usual and really deep piercing is impossible.

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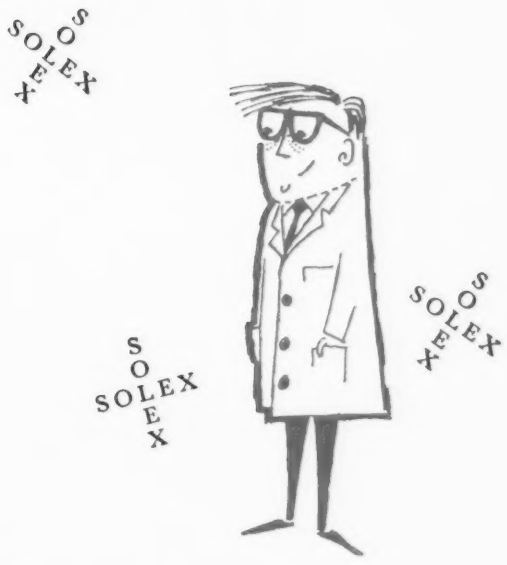

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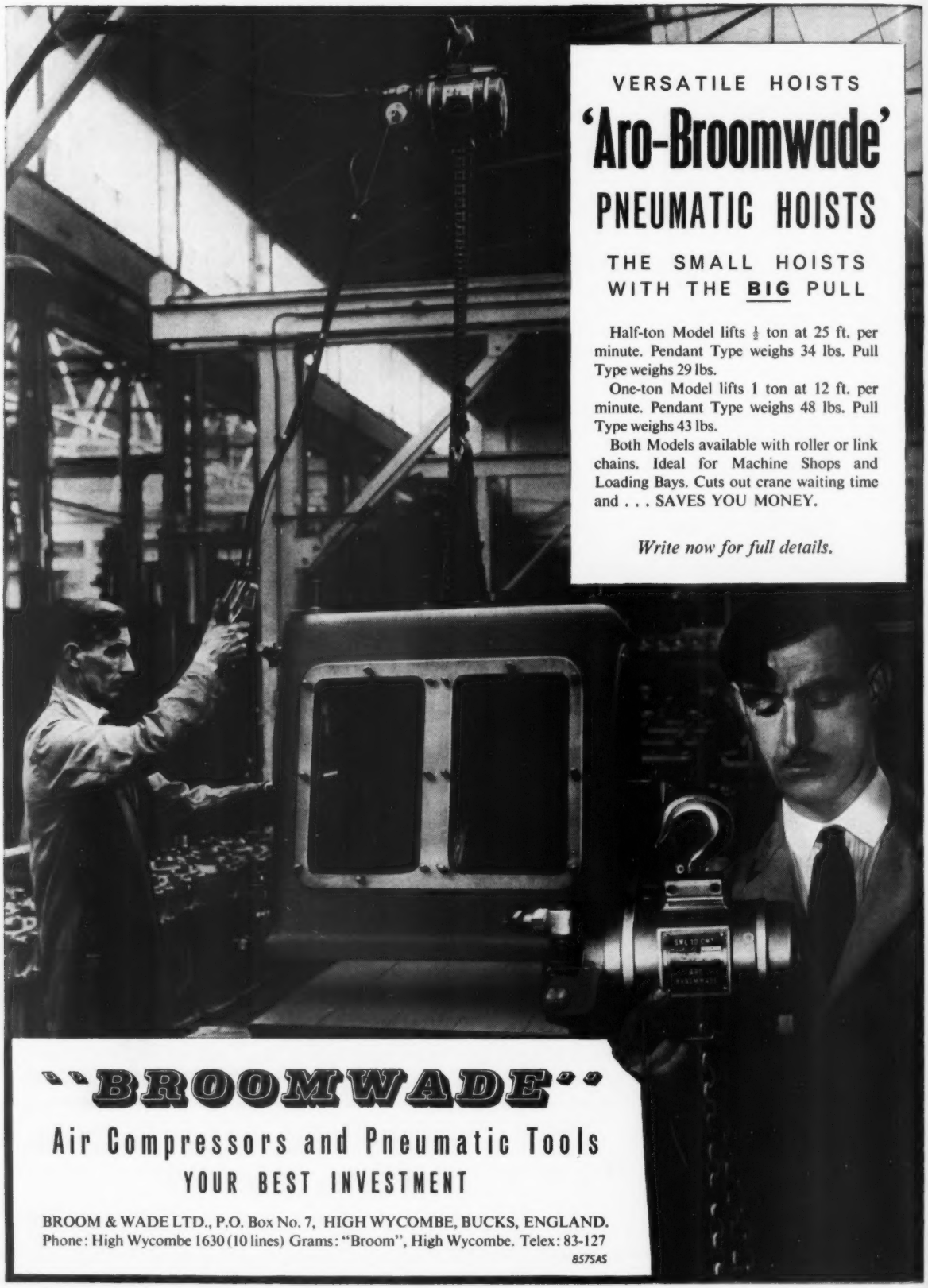

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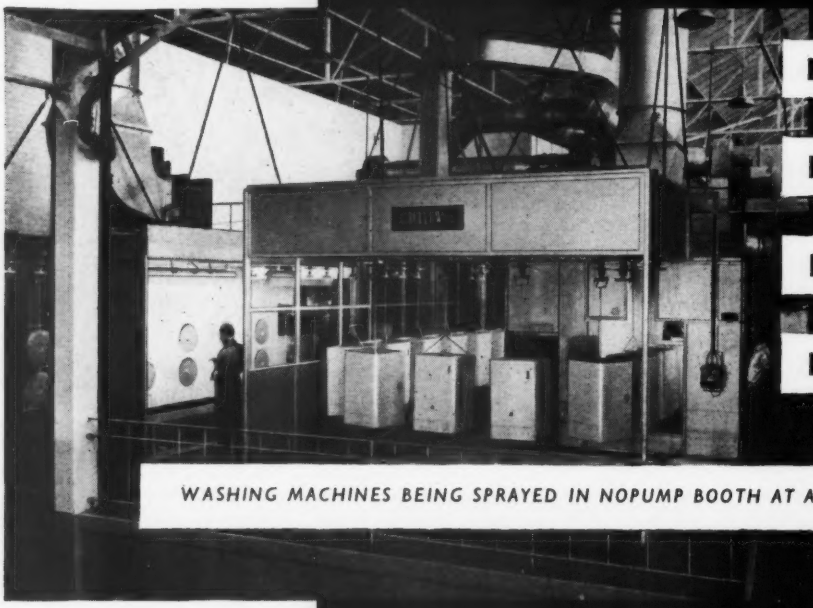

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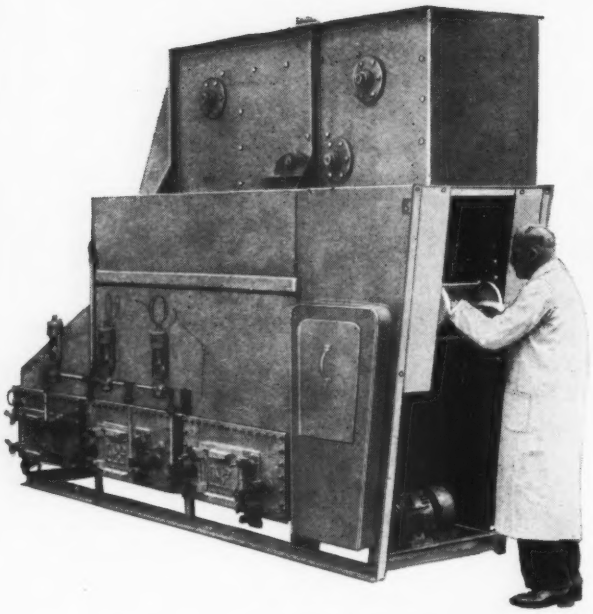

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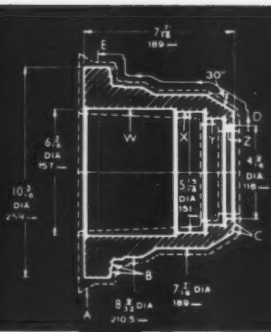
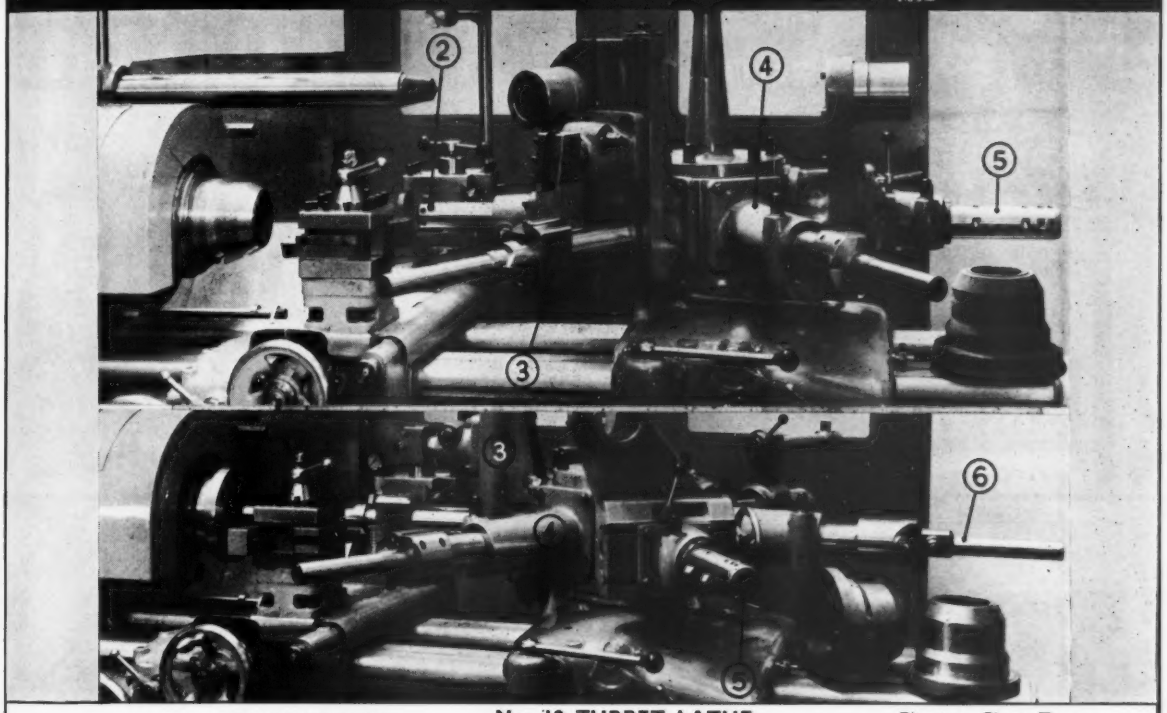
TOOLING LAYOUT No. 18





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Floor to Floor Times :
1st Process 15 mins.
2nd Process 15 mins.

DESCRIPTION OF OPERATION	Tool Position: Hex. Turret	Tool Position: Cross-slide	Spindle Speed R.P.M.	Max. Cutting Speed: Feet per min.	Max. Cutting Speed: Metres per min.	Feed: Cuts per inch	Feed: m/m. per rev.
1st Process							
1. Grip on "A" in 3-Jaw chuck using loading attachment	1	—	—	—	—	—	—
2. Rough bore "Z"	2	—	125	149	45·4	124	·205
2. Rough double face "B" & "C"	—	S.T.	125	344	105	124	·205
3. Copy turn "D" to "E"							
1st cut — Roughing	—	Rear	125	344	105	64	·397
2nd cut — Finishing	—	Rear	240	667	203	124	·205
4. Remove from chuck using unloading attachment	1	—	—	—	—	—	—
2nd Process							
1. Grip on 7 7/16" dia. in 3-Jaw chuck	—	—	—	—	—	—	—
2. Rough face end (two cuts)	—	S.T.	125	368	112	64	·397
3. Rough turn 10 3/8" dia. (two cuts)	—	S.T.	125	344	105	64	·397
4. Rough bore "Z" & "W" dias. and knee turn 10 3/8" dia.	3	—	155	413	126	64	·397
5. Rough bore "Y" & "X" dias.	4	—	155	241	73·4	64	·397
6. Undercut and chamfer bores	5	—	125	207	63	Hand	Hand
7. Microbore "Y," "X" & "W" dias.	6	—	240	389	118·5	88	·289
8. Remove from chuck	—	—	—	—	—	—	—

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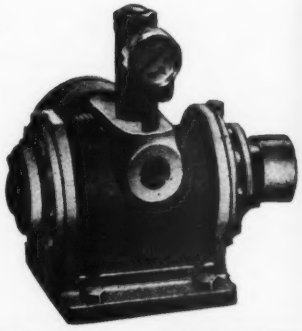

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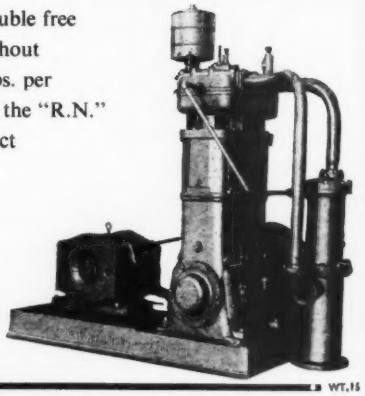

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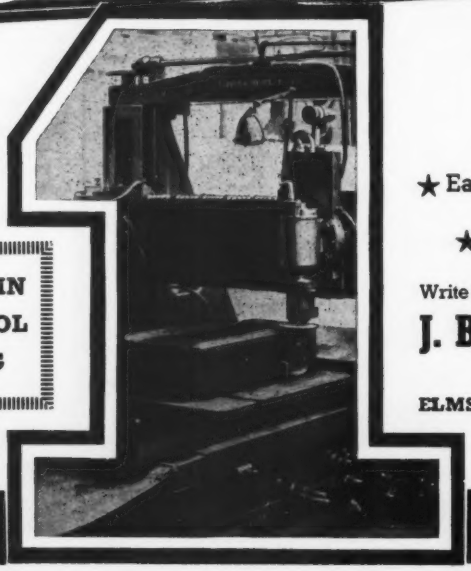

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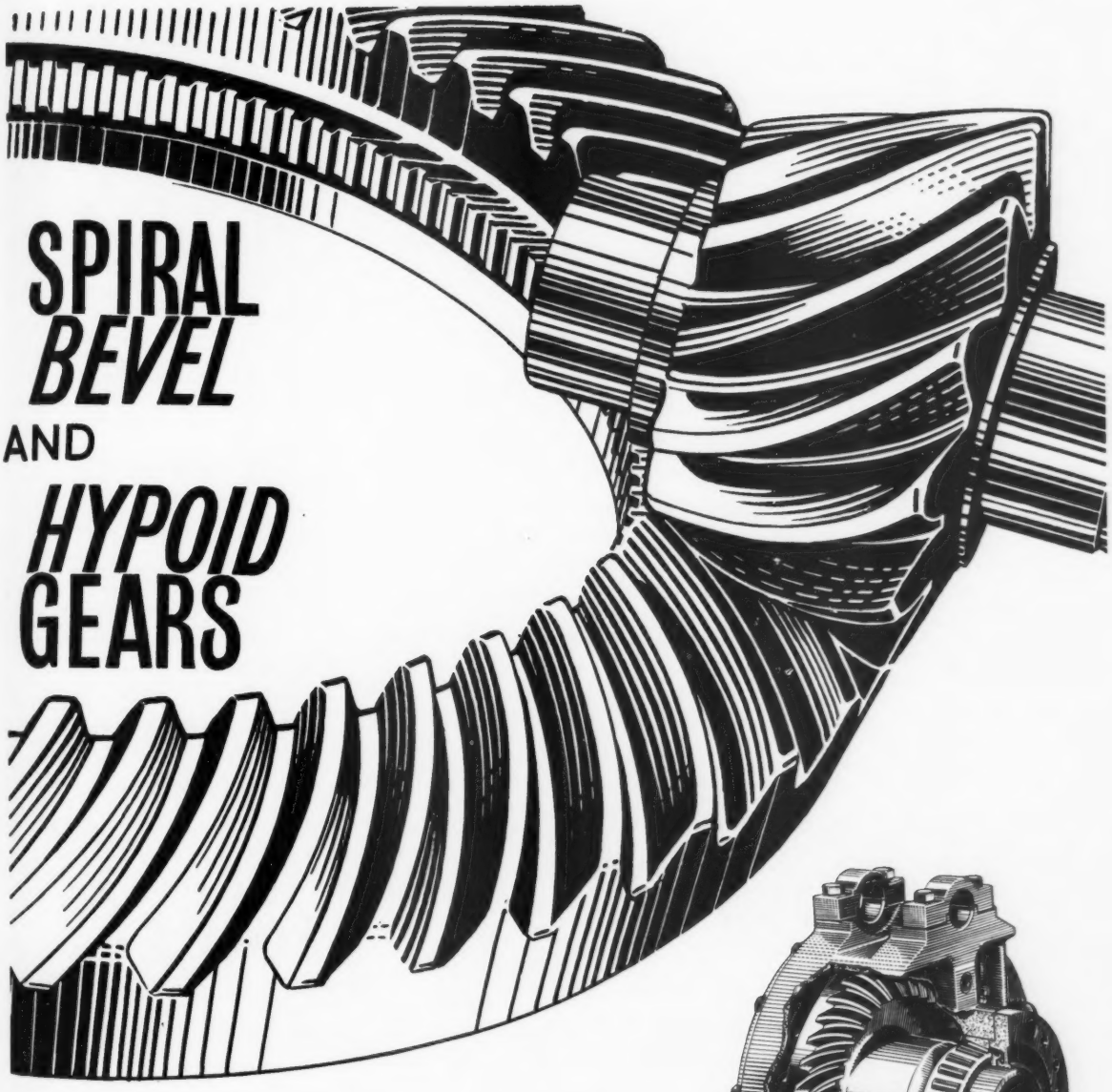

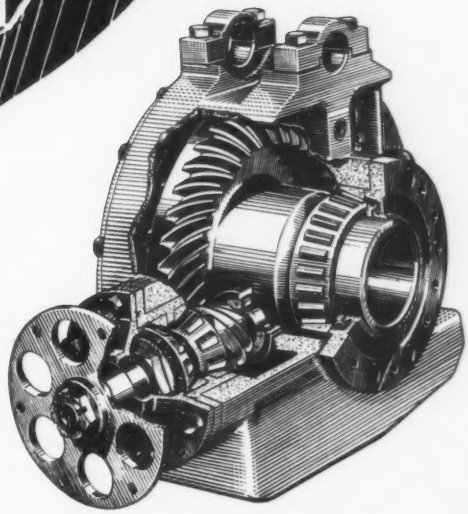

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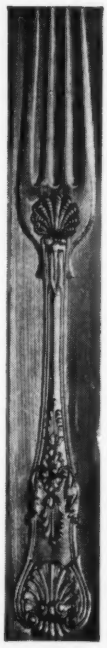

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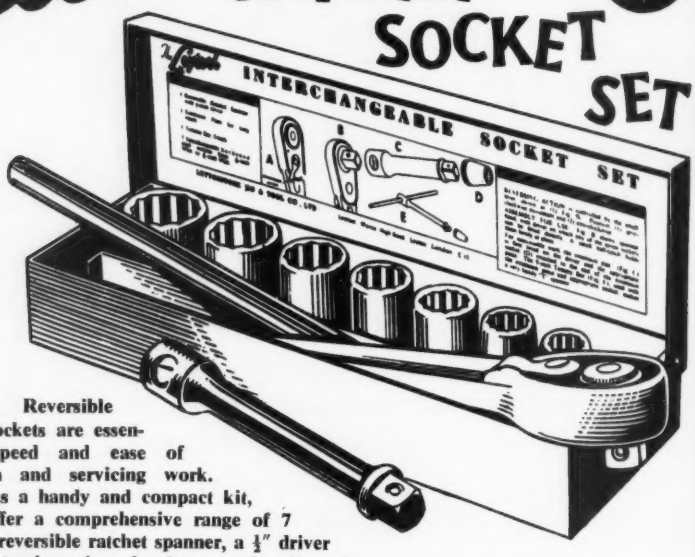

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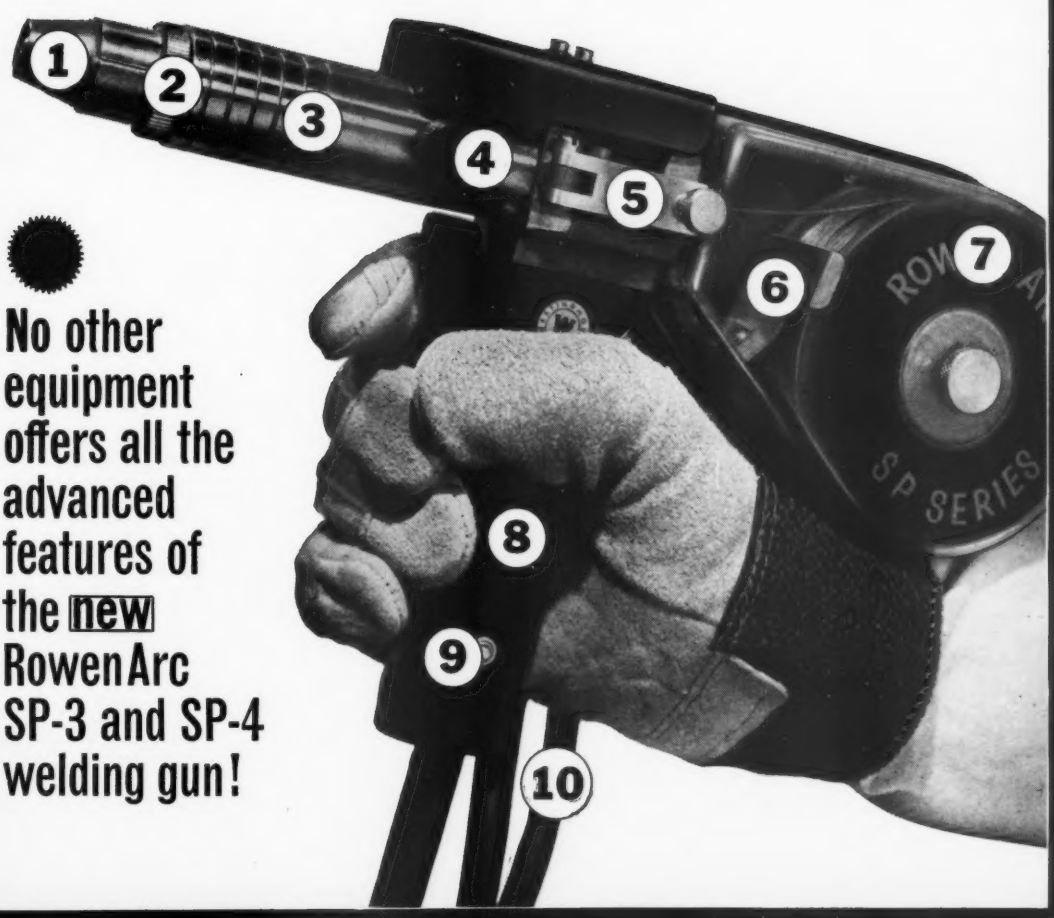

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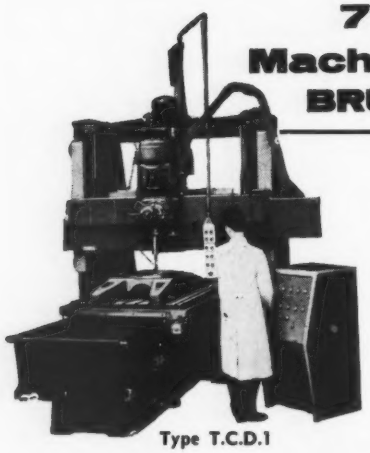

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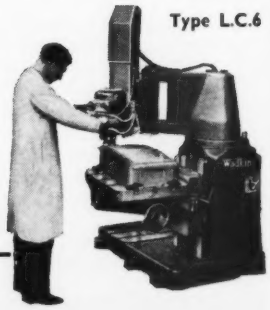

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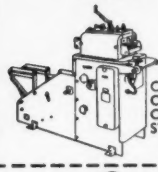

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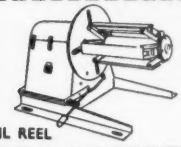

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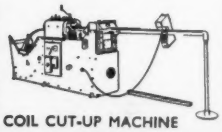

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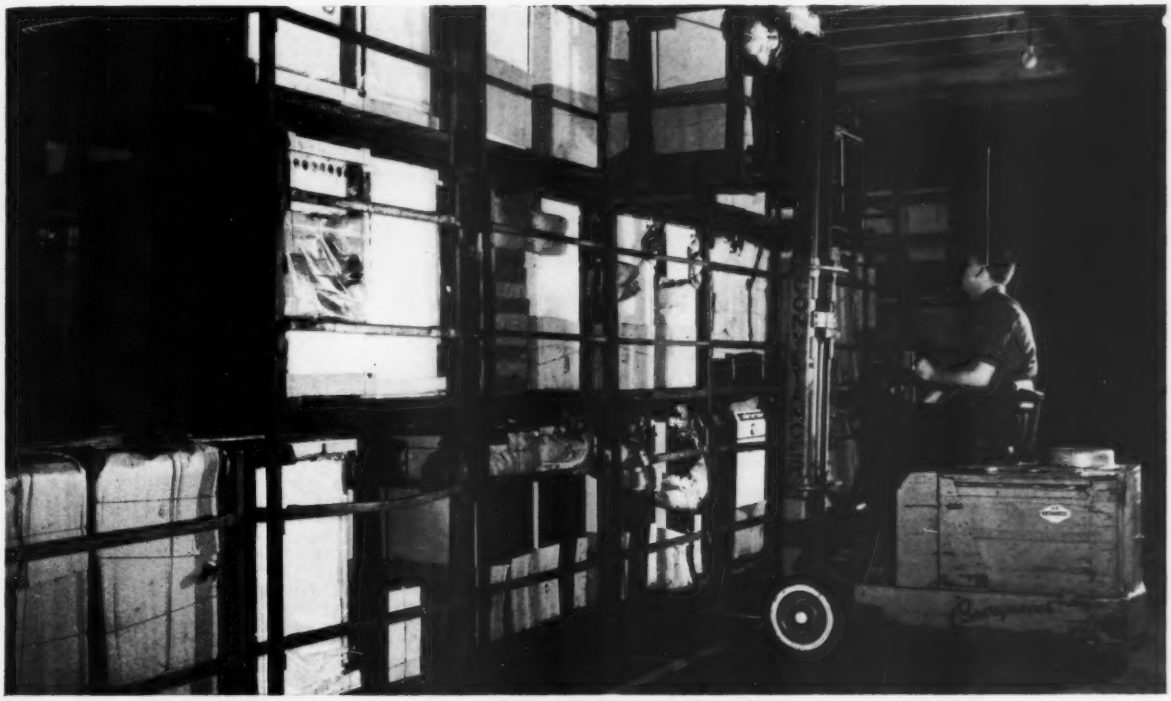

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The Glasgow and Western Division of The Scottish Gas Board recently reorganised its storage system with R.O. pallets and shelving. The resulting increase in efficiency was a 5% cut in labour and a speed-up in delivery of 50%.

Rubery Owen palletisation and shelving schemes often show this kind of saving — further proof that Rubery Owen, Wrexham, have the facilities and experience to solve every storage and handling problem. Perhaps yours?

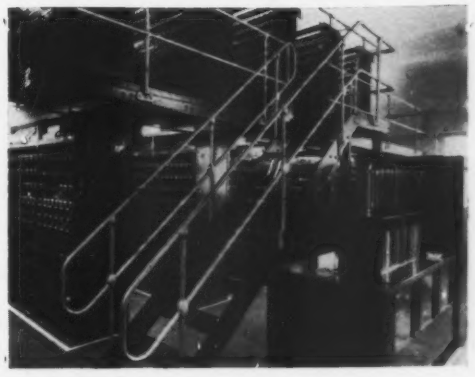
TECHNICAL DATA

The storage system of the Glasgow and Western Division of The Scottish Gas Board consists of a central store at Glasgow and sub-area stores at Greenock, Dumbarton, Kilmarnock and Coatbridge. Together they supply 68% of the gas appliance users in Scotland. All stores are operated on the same lines and Rubery Owen, Wrexham, supplied the complete equipment.

At the Glasgow stores 1,596 sq. ft. of shelving supply 12,048 cubic ft. of storage space. Fourteen storemen operate the system and in the course of one five-day week have supplied 2,893 customers with their requirements. The speed-up in delivery is an easy 50%.

In the cooker store there is complete palletisation. R.O. post pallets with retaining bars are used. Each pallet contains four cookers and the pallets can be stacked four high, saving space and minimising damage.

The S.G.B. Glasgow and Western Division stores installation—another example of the time and labour saving schemes devised for important clients by R.O., Wrexham. We'd be pleased to do the same for you.



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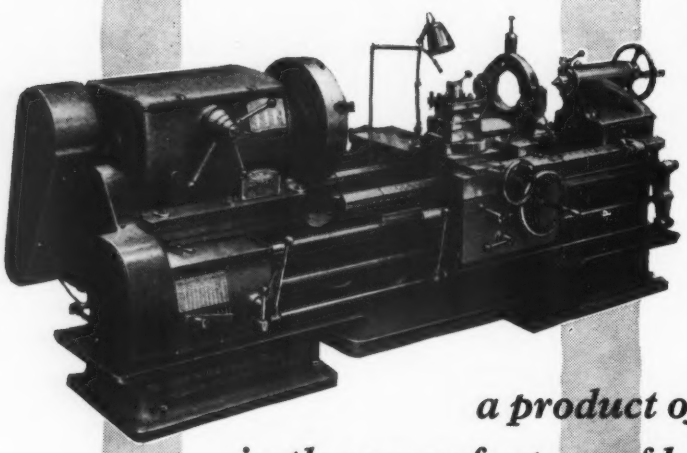

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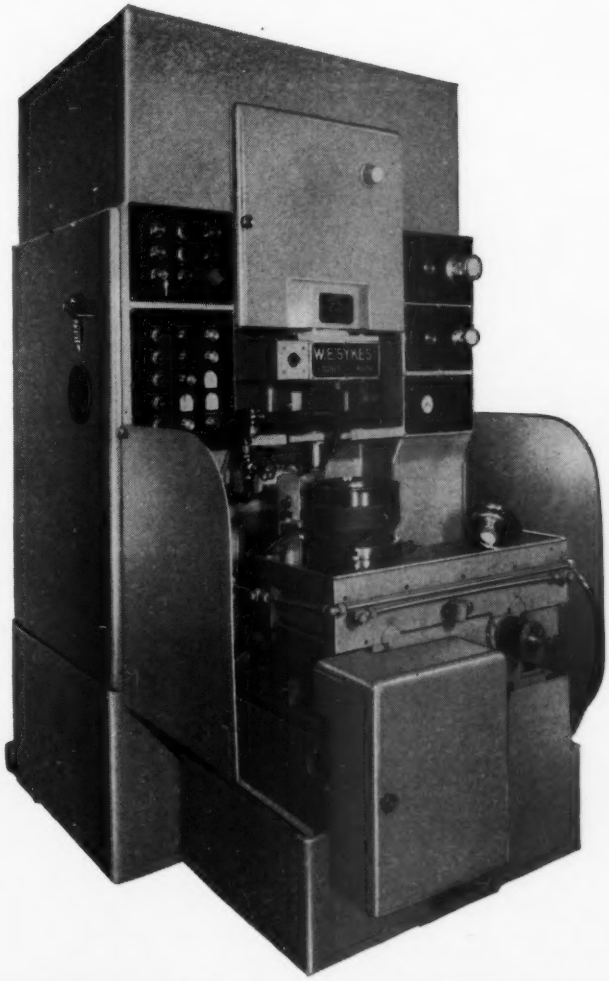
for medium batch production



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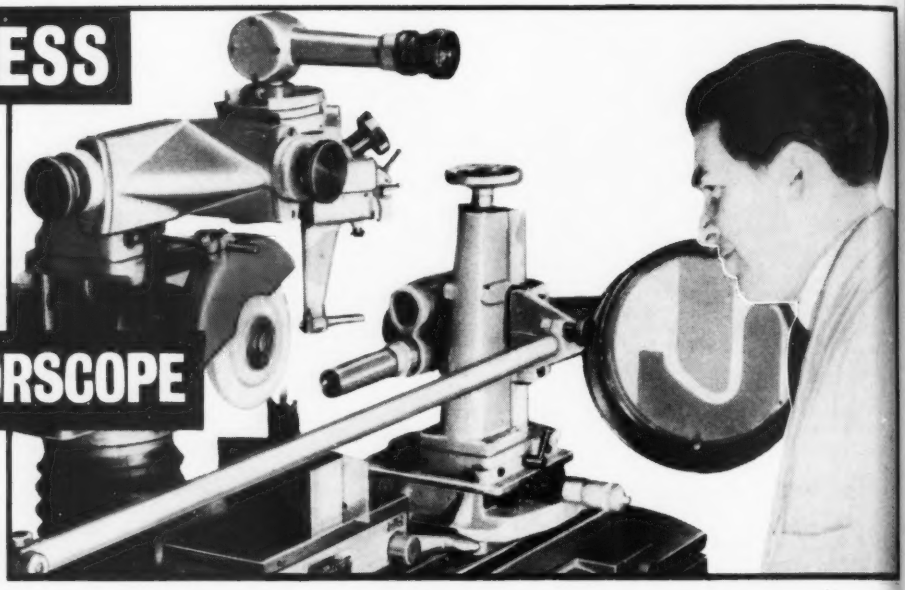

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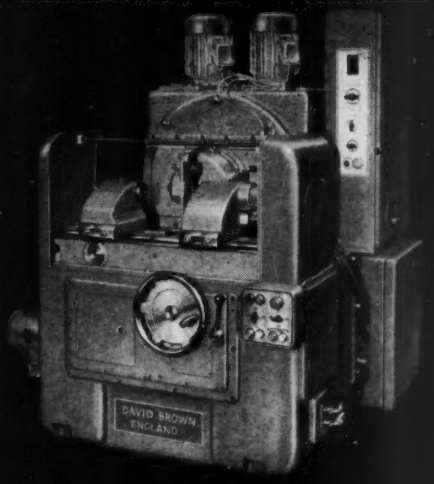

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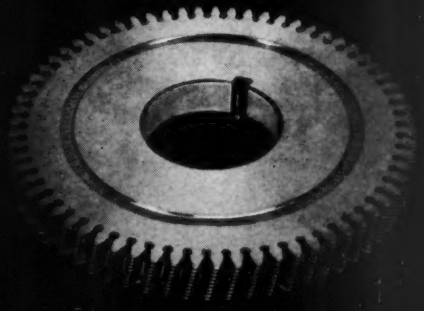

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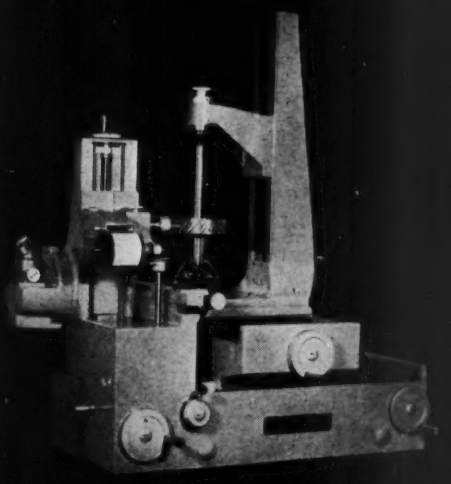

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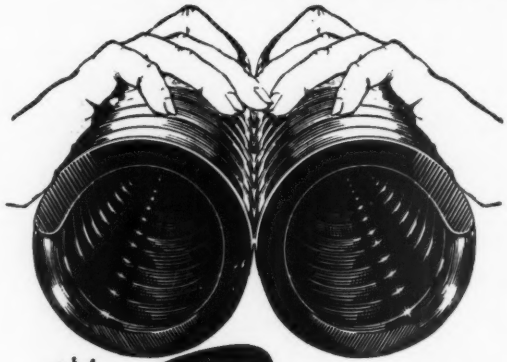

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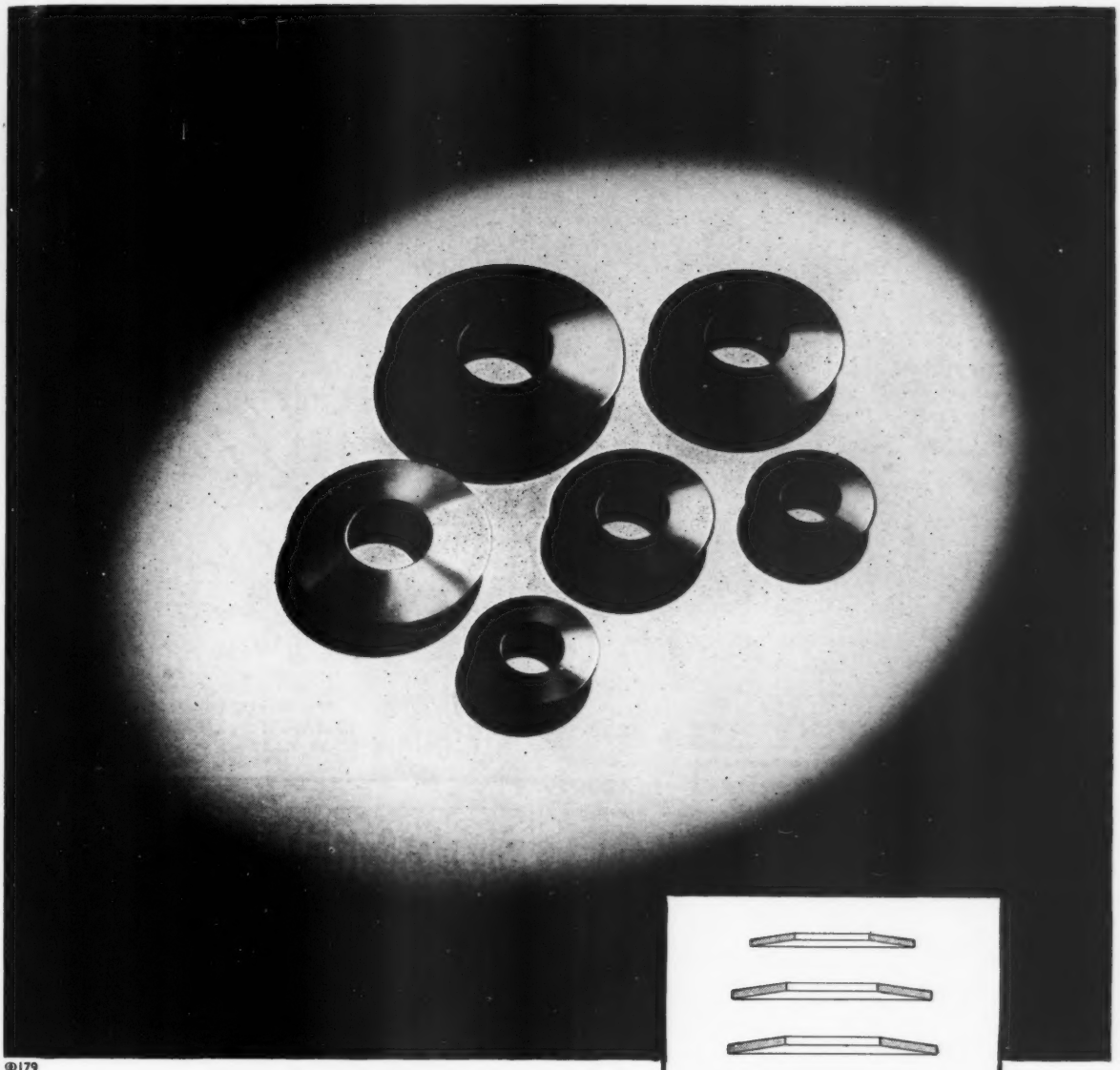

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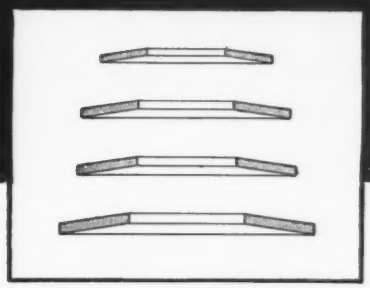

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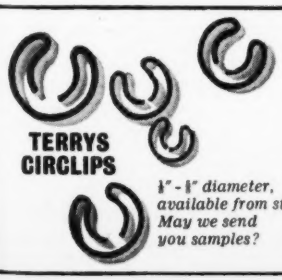

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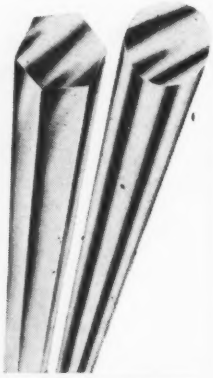

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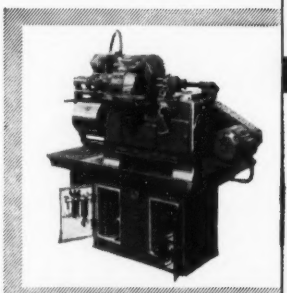

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CAPACITY

Round Bars. Dia.	1"
Hexagon Bars. A/F	0.71"
Square Bars. A/F	⅞"
Maximum Travel of Tailslide	2"
Maximum Travel of cross slide	⅝"

SPINDLE SPEEDS

Speed Range	810-2,500 r.p.m.
No. of Speeds	14

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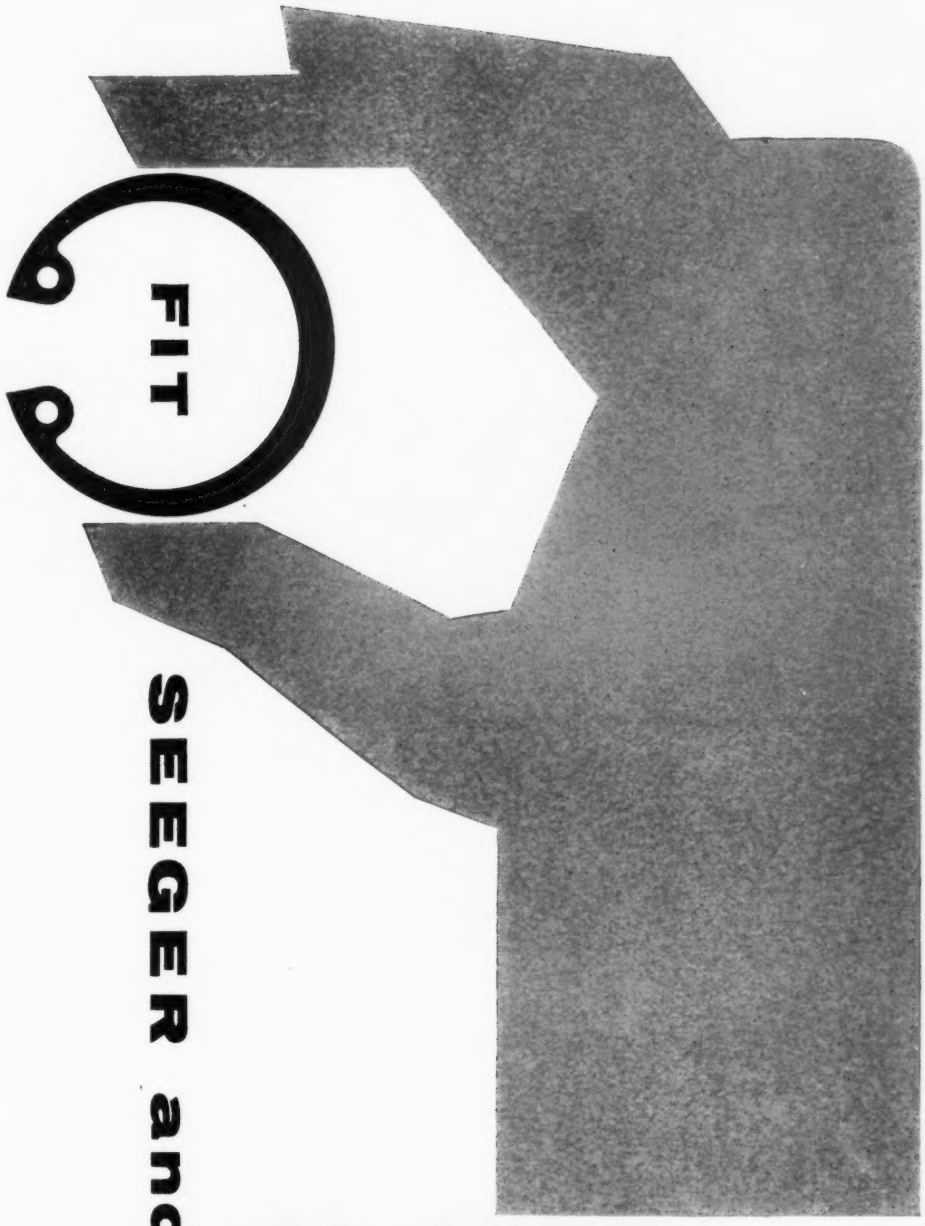

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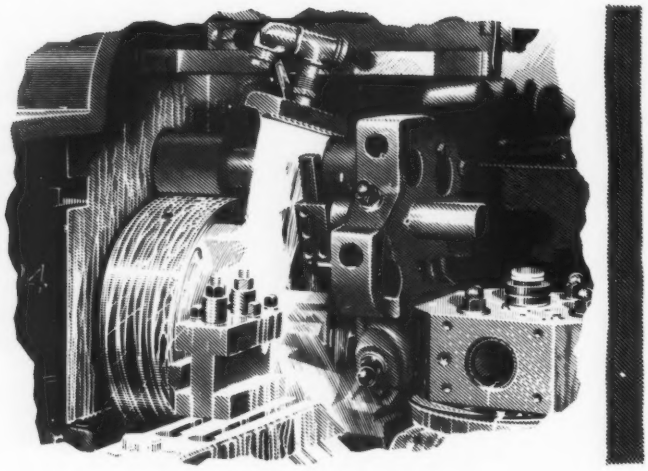

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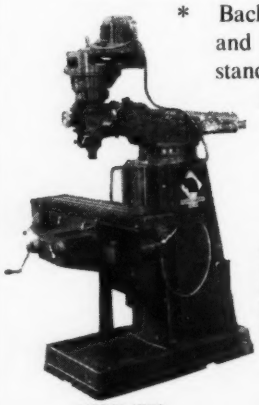

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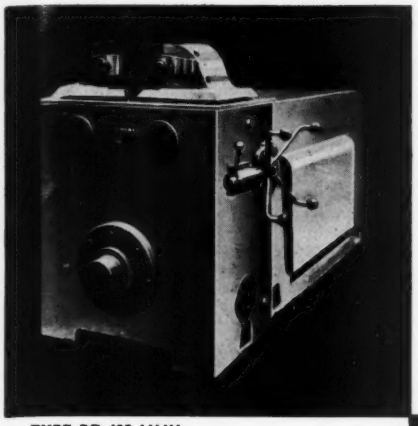

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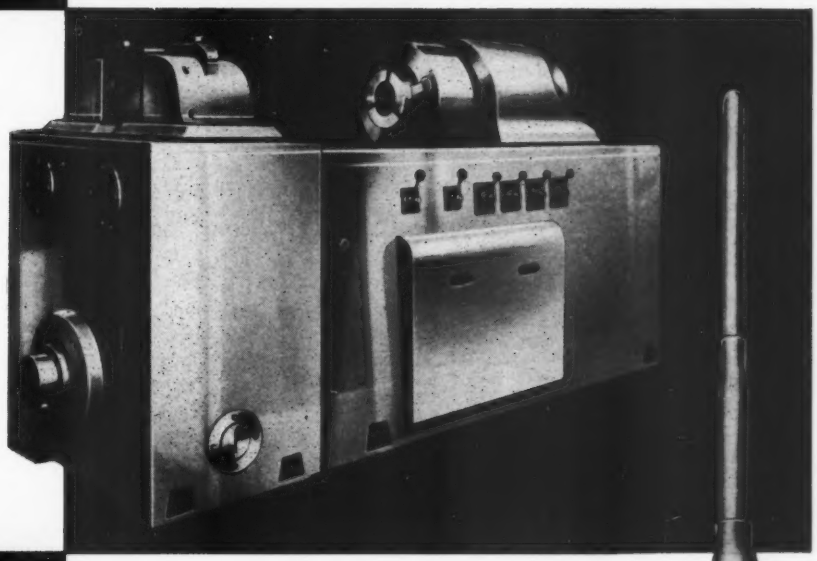

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'RIBBACK' HAMMERING MACHINE
WITH AUTOMATIC FEED

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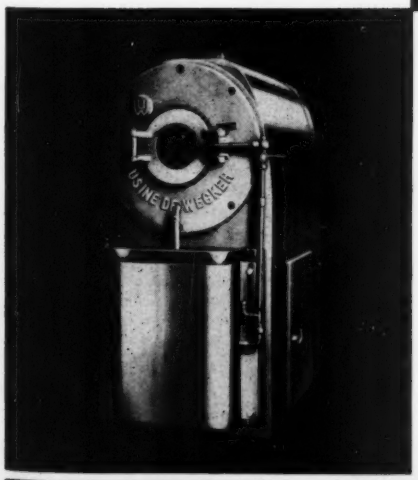
TYPE RU 40



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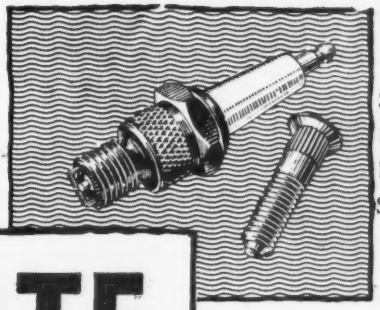

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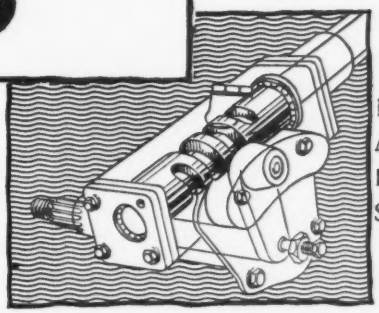

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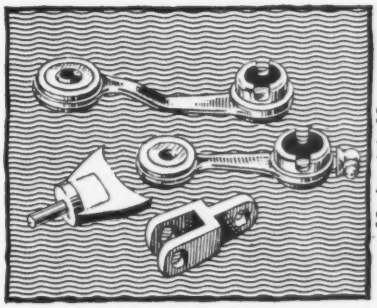
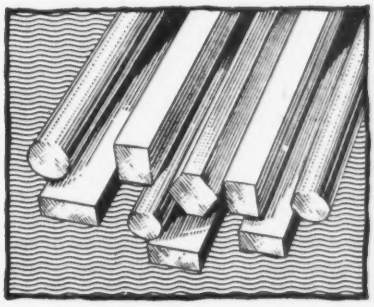


STEELS FOR FORGINGS AND DROP STAMPINGS



MILD, CARBON AND ALLOY STEEL BARS

RANGE OF QUALITIES

Steels in the carbon range 0.080/0.85%
Case-hardening steels.
Free-cutting steels.
Low alloy steels.
For machining, bright drawing, forging, drop stamping and general engineering.

RANGE OF PRODUCTS

Billets from 3″ sq. upwards.
Rounds from $\frac{3}{8}$″ to $9\frac{1}{2}$″.
Hexagons from $\frac{3}{8}$″ to $3\frac{5}{8}$″.
Squares from $\frac{3}{8}$″ to $4\frac{1}{2}$″.
Flats in certain sizes.
Colliery roof supports and accessories.
Special T.H. yielding arches.

COILED BARS

Rounds $\frac{3}{8}$″ to $\frac{29}{64}$″ in 500 lb. coils.
Rounds $\frac{5}{8}$″ to $1\frac{1}{16}$″ in 900 lb. coils.
Hexagons $\frac{3}{8}$″ to $\frac{9}{16}$″ in 500 lb. coils.
Hexagons $\frac{17}{64}$″ to 1″ in 900 lb. coils.
Coils may be split if required.

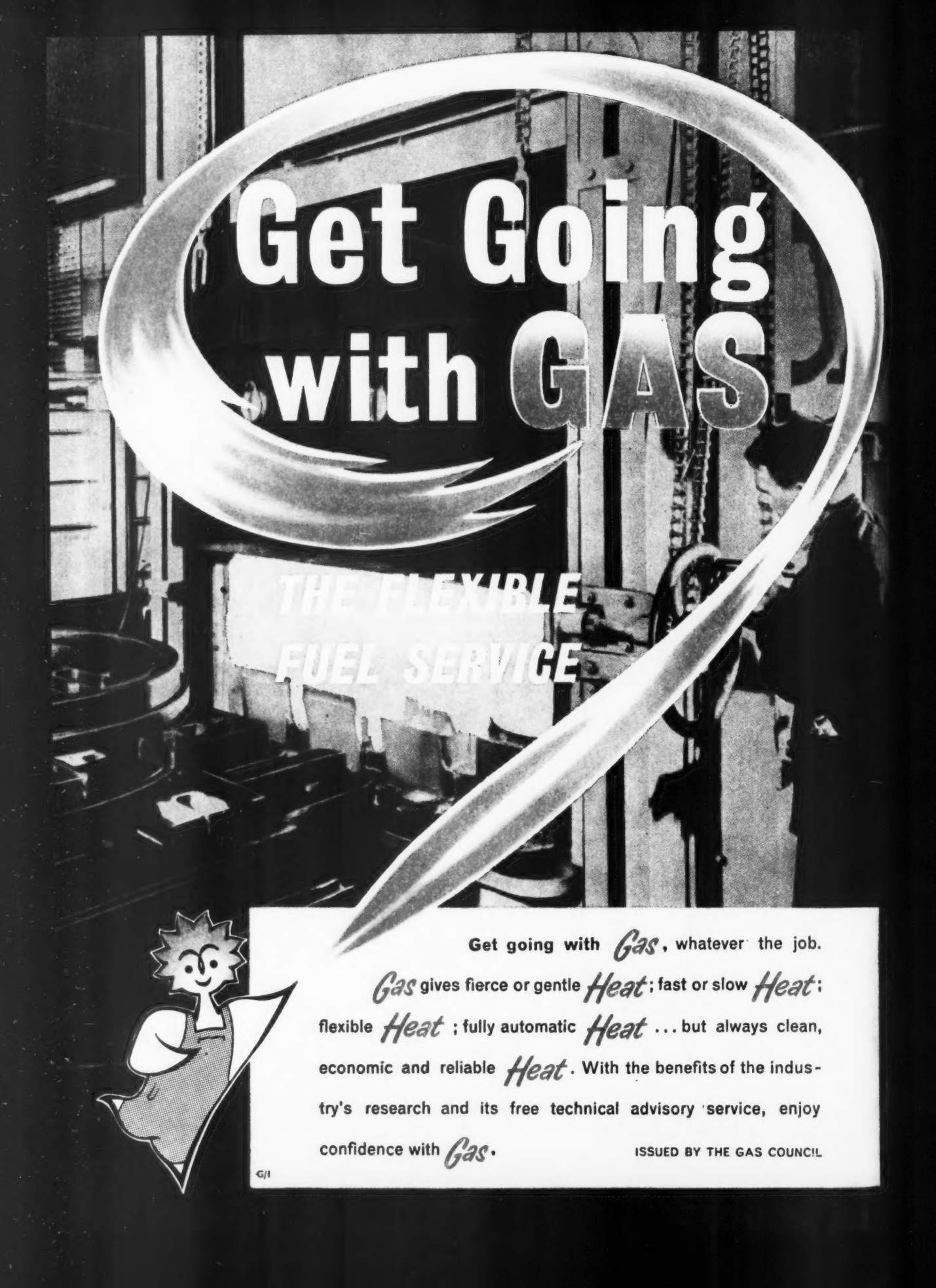
COLD FORGING QUALITY WIRES

0.240″ to 0.550″ in 500 lb. coils.
0.550″ to 1.000″ in 900 lb. coils.
Coils may be split if required.

THE PARK GATE IRON & STEEL COMPANY LIMITED ROTHERHAM

A TI Company

TELEPHONE: ROTHERHAM 2141 (15 lines) TELEGRAMS: YORKSHIRE, PARKGATE, YORKS. TELEX 54141



Get going with *Gas*, whatever the job. *Gas* gives fierce or gentle *Heat*; fast or slow *Heat*; flexible *Heat*; fully automatic *Heat* ... but always clean, economic and reliable *Heat*. With the benefits of the industry's research and its free technical advisory service, enjoy confidence with *Gas*.

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